EORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

# PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ____

oject No. A-3648 GTRI/~~GIT~~ DATE 9 / 14 / 83

oject Director: Gerry Hill ~~School~~/Lab EML

ponsor: Hughes Aircraft Company

ype Agreement: P. O. Number S8-893512-LJS

ward Period: From 9/7/83 To ~~5/27/84~~ 10-27-84 (Performance) 5/27/84 (Reports)

ponsor Amount:

| | This Change | Total to Date |
|---|---|---|
| Estimated: | $ 60,177 | $ 60,177 |
| Funded: | $ 60,177 | $ 60,177 |

ost Sharing Amount: $ ____ Cost Sharing No: ____

tle: "Millimeter Wave Mixer Diodes, Phase III"

DMINISTRATIVE DATA — OCA Contact Frank H. Huff X4820

Sponsor Technical Contact:

Mr. B. L. Walsh
Chief Scientist
Hughes Aircraft Company
Space Communications Group
P.O. Box 92919
El Segundo, California 90009

2) Sponsor Admin/Contractual Matters:

F. W. Manena
Bldg. S12, Mail Station W323
Hughes Aircraft Company
P.O. Box 92919-Airport Station
Los Angeles, California 90009
(213) 648-1855

fense Priority Rating: 3

Military Security Classification: ____

(or) Company/Industrial Proprietary: ____

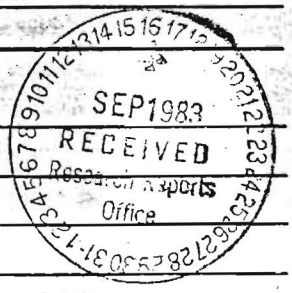
ESTRICTIONS

e Attached ____ Supplemental Information Sheet for Additional Requirements.

avel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

uipment: Title vests with sponsor; however, none authorized/proposed.

OMMENTS:




OPIES TO:

oject Director
esearch Administrative Network
esearch Property Management
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
GTRI
Library
Project File

ORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date Nov. 5, 1984

ct No. A-3648 ~~School~~/Lab EML

ides Subproject No.(s)

ct Director(s) Gerry Hill GTRI / ~~GTRI~~

sor Hughes Aircraft Company

Millimeter Wave Mixer Diodes, Phase III

tive Completion Date: 10/27/84 (Performance) 10/27/84 (Reports)

t/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

nues Project No. Continued by Project No.

ES TO:

ct Director
rch Administrative Network
rch Property Management
unting
rement/EES Supply Services
rch Security Services
rts Coordinator (OCA)
Services

Library
GTRI
Research Communications (2)
Project File
Other A. Jones; M. Heyser

A-3648

Del No. 1

Status Report No. 1

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
7 September 1983 through 30 September 1983
P. O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The verification of contract award for the Millimeter Wave Mixer Diode - Phase III was received on September 14th. The deliverable diodes for this program will be similar to those delivered on phase II.

## GENERAL

### GaAs Material

Three Gallium Arsenide wafers have been ordered from Raytheon Special Microwave Devices Operation (SMDO). The request was to duplicate within 10%, all of the electrical and physical properties of the best phase II wafer, 8A499. This particular wafer was grown at the Ratyheon research facility in Waltham, Mass. It is our hope that the SMDO material when processed will yield diodes of the same high quality. SIMS Analysis will be completed on this material upon receipt.

### E-beam Evaporator

The E-beam evaporator is being modified to provide greater pumping capacity. A CTI corporation cryopump is presently being installed in the interlock chamber pumpout port. This additional pumping capacity will permit lower pressure to be maintained during metal deposition. The cryopump will be especially useful in removing water vapor which is released in the vacuum chamber during deposition; a problem encountered during phase II.

### Test Equipment

A request has been made for the return of the diode test equipment and photomasks that were sent to Hughes upon completion of phase II. Mr. Walsh indicated that he would ship these materials to Georgia Tech immediately.

PLANS FOR NEXT MONTH

- Hopefully receive the GaAs materials.
- Purchase SIMS service.
- Test E-Beam system.

A-3648

Del No. 2

# Status Report No. 2

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 October 1983 through 31 October 1983
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The program activity for this reporting period has been limited while awaiting the delivery of GaAs material.

## GENERAL

### GaAs Material

Raytheon (SMDO) has responded to the purchase order for the GaAs material. Their response is that our material requirements can be fulfilled with one 2 inch diameter wafer rather than 1 inch squares previously supplied by their research laboratory. The latter are no longer available. Delivery of this material is scheduled for the end of October.

### E-Beam Evaporator

The modification of the E-beam evaporator has been completed. The mechanical and turbo molecular pumps have been eliminated and replaced by cryo pumps for both roughing and interlock pumpdown. Excellent pumpdown performance has been realized with no chance of oil contamination. A system base pressure of $1 \times 10^{-10}$ torr is easily achieved. The new system schematic is shown is figure one.

### Test Equipment

The life test equipment requested last month from Hughes has been received. New diode clamping chucks are being fabricated.

## PLANS FOR NEXT MONTH

- Receive and evaluate the GaAs material.
- Begin diode processing.

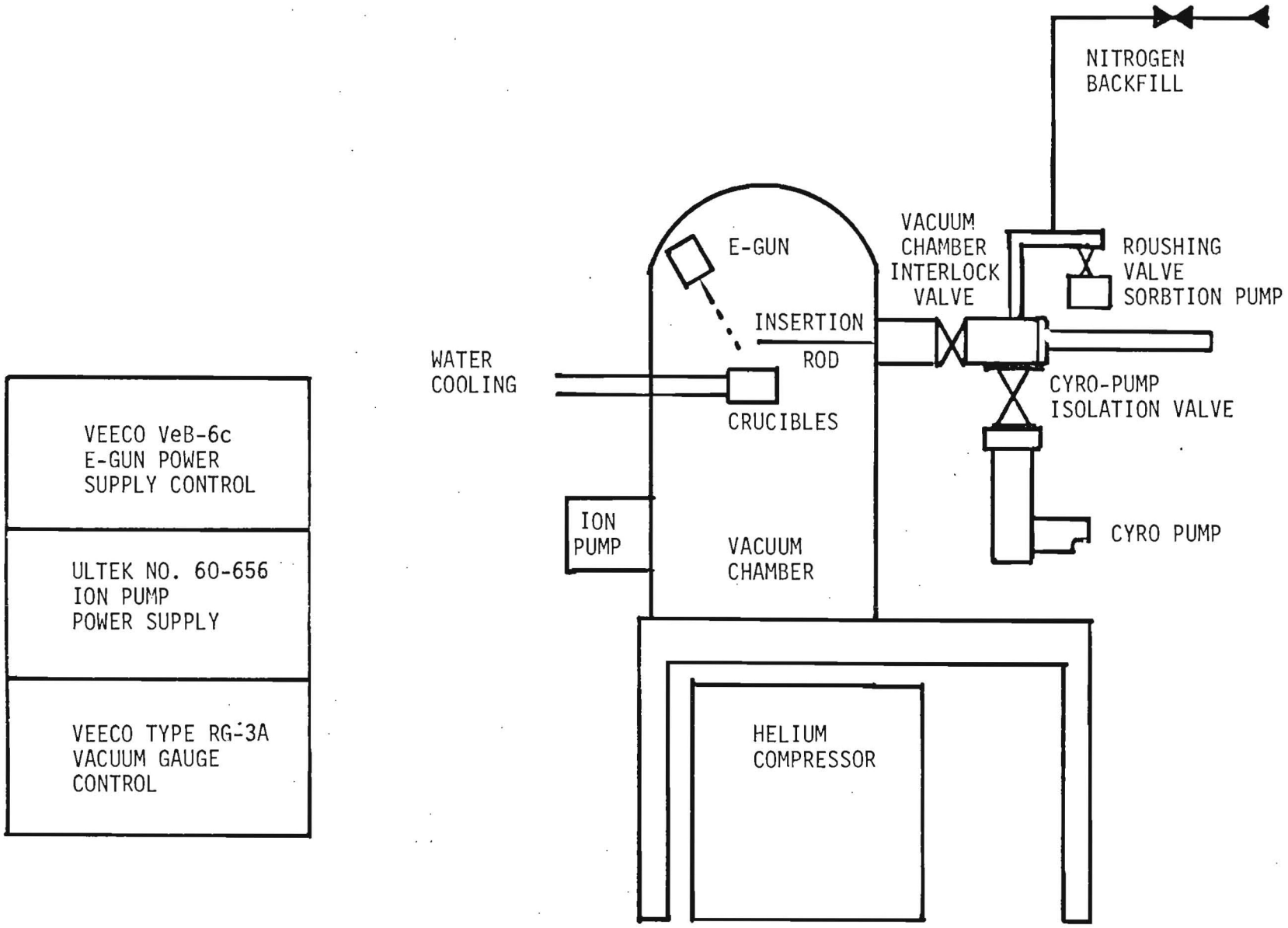



Figure 1. E-beam system block diagram.

## ADDENDUM

### GaAs MATERIAL

The GaAs has been received; however, the material characteristics are not nearly as good as expected. Raytheon has agreed to grow additional material having a sharper $NN^+$ interface. Paul Whittier (Raytheon) feels they can do this within a month, perhaps less. Figures 1 and 2 show the impurity profiles of the past phase two and the new GaAs material.

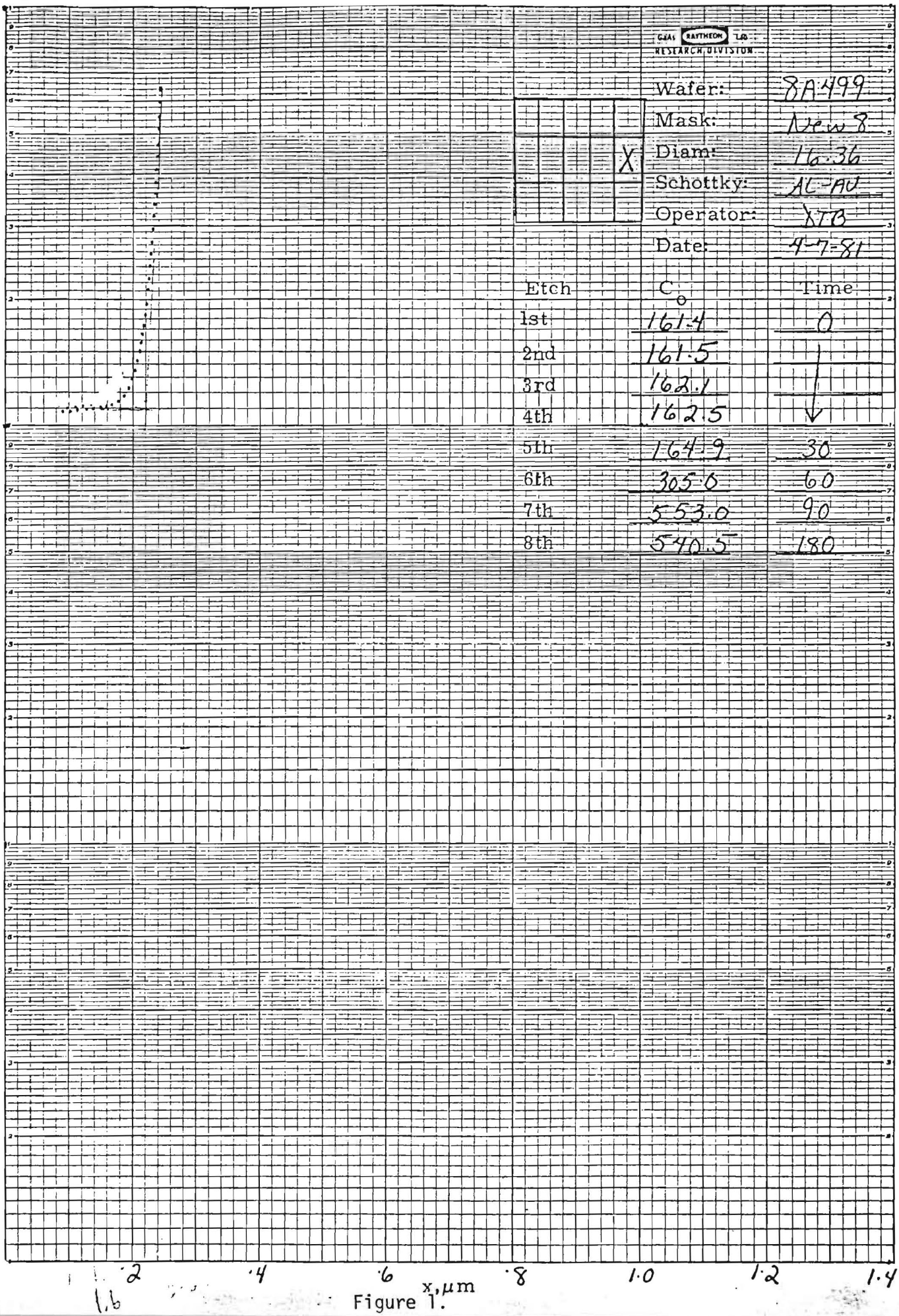

GaAs RAYTHEON Co.
RESEARCH DIVISION
Wafer: 8A499
Mask: New 8
Diam: 16.36
Schottky: AL-AU
Operator: XTB
Date: 4-7-81
Etch
Co
Time
1st 161.4 0
2nd 161.5
3rd 162.1
4th 162.5
5th 164.9 30
6th 305.6 60
7th 553.0 90
8th 540.5 180
18
17
16
15
.2
.4
.6
.8
1.0
1.2
1.4
x, μm
1.6

Figure 1.

GaAs EPITAXIAL GROWTH LAB - SMDO NORTHBORO

18

C ~ 2500 pF

Wafer: 1493

Mask: ~

Diam: 2945

Schottky: HG-

Operator: AB

Date: 10/21/80

| Etch | $C_o$ | d(um) |
|---|---|---|
| Surf. | | |
| 1st | | |
| 2nd | | |
| 3rd | | |
| 4th | | |
| 5th | | |
| 6th | | |

7

d (um)

Figure 2

A-3648

Del No. 3

Status Report No. 3

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 November 1983 through 30 November 1983
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The program activity for this reporting period has been limited while awaiting the delivery of the Gallium Arsenide material.

## GENERAL

### GaAs Material

The GaAs wafer received and reported in last months status letter Addendum was returned to Raytheon. The replacement GaAs is promised for delivery on December 9th. A telcon with Paul Whittier (Raytheon) indicated that they were running two weeks behind schedule. Meanwhile all that can be done is preparation of the process equipment and supplies.

A-3648

Del No. 4

Status Report No. 4

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 December 1983 through 31 December 1983
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The diode program activity is still being limited due to the lack of GaAs material.

## GENERAL

### GaAs Material

Raytheon has been unable to deliver the GaAs per their December schedule. Equipment problems have been cited as the cause for their delay. An apparent failure in the flow control system was not allowing them to produce the proper impurity profile. During latest conversation with Paul Whittier (Raytheon) on January 6th, he indicated the delivery should be made on the 13th of January. A followup phone call to Raytheon will be made on this date.

A-3648

Del No. 5

# Status Report No. 5

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 January 1984 through 31 January 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The mixer diode program activity is still being delayed due to lack of GaAs material.

## GENERAL

### GaAs Material

Paul Whittier (Raytheon) reports that the GaAs is presently being grown. Their latest problem is that they have had difficulty in obtaining substrate material suitable for our program. Apparently their substrate supplier (Sumitomo) has not been able to supply $N^+$ silicon doped material in a timely fashion. Paul has tried substrate material from Laser Diode; however, it was totally unacceptable because of the poor surface and high defect density.

It is unfortunate that these additional problems have occurred, thereby upsetting the program schedule. Once the material is received, a new schedule can be established.

A-3648

Del No. 6

Status Report No. 6

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 February 1984 through 29 February 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

INTRODUCTION

The mixer diode program is still being delayed due to lack of GaAs material.

GENERAL

The latest word from Raytheon concerning the diode material is that they have had a series of bad runs; however, they presently have some material that meets our specifications and have shipped. It was anticipated that the material would be received by this writing so that the impurity profile and wafers could be examined and the information included in this status report. Because the material has not arrived and in the interest of expediting this report, the information will be transmitted to Hughes upon receipt of the material.

A-3648

Del No. 7

Status Report No. 7

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 March 1984 through 31 March 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The mixer diode program is once again underway. Raytheon has delivered a new lot of gallium arsenide epitaxial material. Approximately 10 $cm^2$ of good surface is available on each wafer.

## GENERAL

Two wafers have been received. The impurity profiles included in this report, Fig. 1-4, show an abrupt N $N^+$ interface, acceptable doping densities and layer thicknesses. The 17M63 wafer will be lightly chemically etched in order to remove the increased doping shown on the surface. A portion of this wafer has been submitted to RIBER for SIMS analysis of the impurity profile.

A second portion of the 17M63 wafer has been committed to processing. The photoresist adhesion to the deposited $SiO_2$ during the diode window etch step has been poor. The adhesion promoter, hexamethyldisilazane is thought to be bad and a new supply is on order. The deposition gases and photoresist have at least temporarily been eliminated as the probable cause of poor adhesion.

## SCHEDULE

A request for a no cost extension of 5 months has been initiated. The work and schedule will be adjusted accordingly.

RAYTHEON

9-9083(3/83)

## QUALITY ASSURANCE

GaAs Epitaxial Wafer NUMBER 17M63

r FET Type Devices |__| Low Noise |__| Power |__| Other _____

With |__| Buffer |__| Contact Layer

r IMPATT Type Devices |__| Flat Profile |__| Read Profile |__| Other _____

|__| Single Drift |__| Double Drift with |__| Thick Buffer |__| Standard Buffer |__| p** contact

stomer _____ Customer Order No. _____

_____ Spec. No. Georgia Tech. 17-1

ention _____ Memo No. _____

es Order No. _____ RAMAC No. _____

### SUBSTRATE

plier Sumitoma Electric Crystal Boule No. EX-1720-1 Slice No. 14

entation 2° off 100 toward 110 Pregrowth Thickness 432 um

rier Concentration: _____ $10^{18}$ cm$^{-3}$ Dopant: Silicon

istivity** _____

### ELECTRICAL CHARACTERISTICS

### PHYSICAL CHARACTERISTICS

| Layer Type | Measured Carrier Concentration | Dopant | Thickness |
|---|---|---|---|
| Buffer | 7.2 x $10^{15}$ cm$^{-3}$ | Si | 5.5 um |
| Buffer | x10 cm$^{-3}$ | | um |
| Active | 11.0 x $10^{16}$ cm$^{-3}$ | Si | 0.22 um |
| Active | x$10^{16}$ cm$^{-3}$ | | um |
| Spike | x$10^{17}$ cm$^{-3}$ | | ( ) um |
| Contact | x10 cm$^{-3}$ | | ($x_p$) um |

fer Size 5.1 cm Area 19.6 cm$^2$ Surface Morphology |__|

: _____ x $10^{12}$ e$^-$-cm$^{-2}$ $V_{knee}$ _____ volts (from Cvs V curve)

: _____ x $10^4$ pF-cm$^{-2}$ Interface _____ um/decade

### DELIVERY AUTHORIZATION

ivery authorized |__| to fill order |__| to fulfill contractual obligations

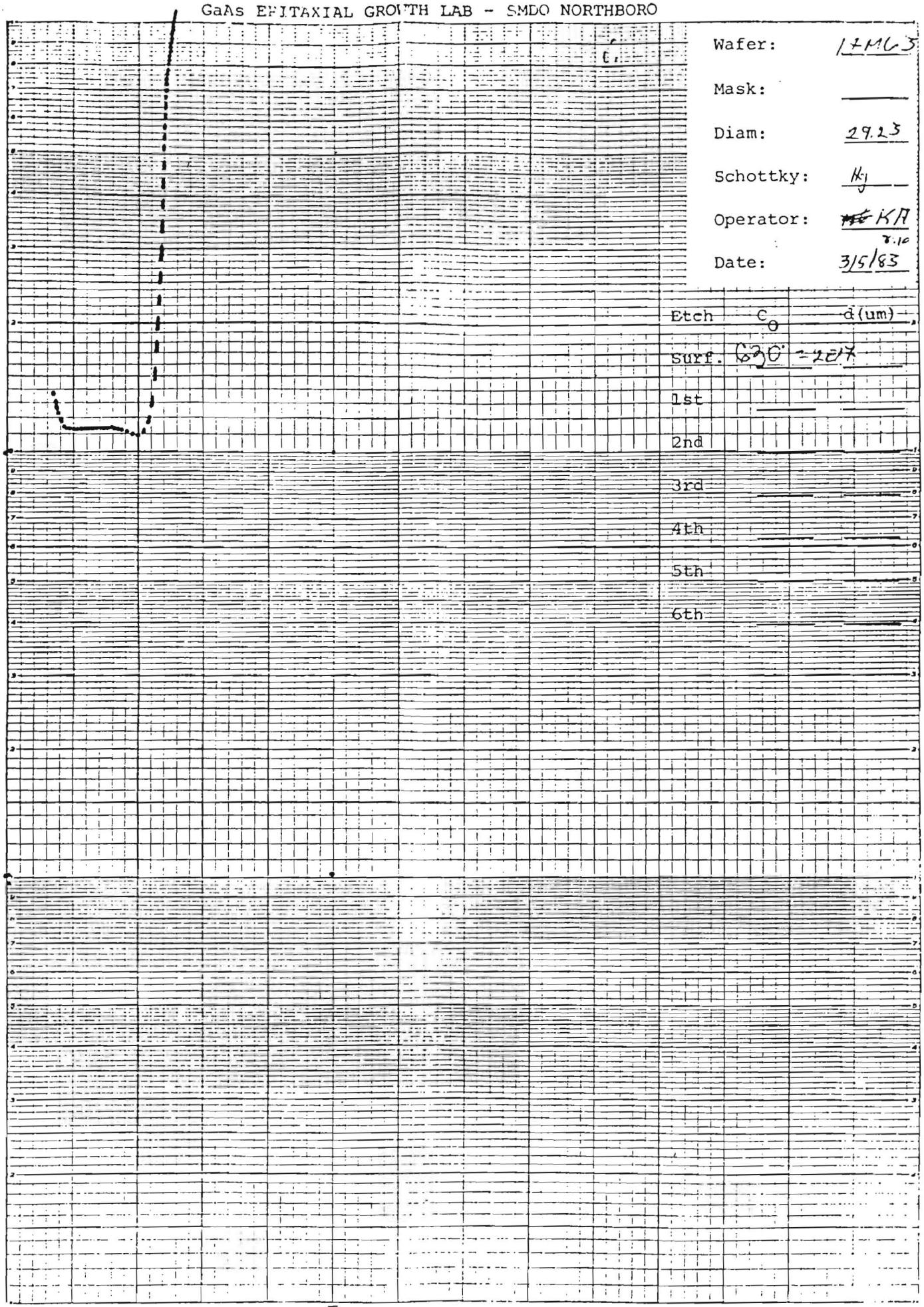
|__| For Device Research |__| For Process Research |__| For Calibration

|__| For Sample Purposes Other _____

unt Ordered _____ Amount Delivered _____

_____ Date: _____

GaAs EPITAXIAL GROWTH LAB - SMDO NORTHBORO



RAYTHEON

39-9083(3/83)

## QUALITY ASSURANCE

GaAs Epitaxial Wafer NUMBER 17M6.4

r FET Type Devices |__| Low Noise |__| Power |__| Other _____

With |__| Buffer |__| Contact Layer

r IMPATT Type Devices |__| Flat Profile |__| Read Profile |__| Other _____

|__|Single Drift |__|Double Drift with |__|Thick Buffer |__|Standard Buffer |__|p** contact

stomer _____ Customer Order No. _____

_____ Spec. No. Georgia Tech

tention _____ Memo No. _____

es Order No. _____ RAMAC No. _____

### SUBSTRATE

plier Sumitomo Electric Crystal Boule No. Ex-17201 Slice No. 15

entation 2° off 100 toward 110 Pregrowth Thickness 432 um

rier Concentration: NA $10^{18}$ $cm^{-3}$ Dopant: Silicon

istivity** _____

### ELECTRICAL CHARACTERISTICS

| Layer Type | Measured Carrier Concentration | Dopant | Thickness |
|---|---|---|---|
| Buffer | 7.2x$10^{17}$ $cm^{-3}$ | Si | 5.5 um |
| Buffer | x10 $cm^{-3}$ | | um |
| Active | 1.1 x$10^{16}$ $cm^{-3}$ | Si | 0.20 um |
| Active | x$10^{16}$ $cm^{-3}$ | | um |
| Spike | x$10^{17}$ $cm^{-3}$ | | ( ) um |
| Contact | x10 $cm^{-3}$ | | ($x_p$) um |

### PHYSICAL CHARACTERISTICS

fer Size 5.1 cm Area 19.6 $cm^2$ Surface Morphology |__|

: _____ x $10^{12}e^{-}$-$cm^{-2}$ $V_{knee}$ _____ volts (from Cvs V curve)

_____ x $10^{4}$pF-$cm^{-2}$ Interface _____ um/decade

### DELIVERY AUTHORIZATION

ivery authorized |__| to fill order |__| to fulfill contractual obligations

|__| For Device Research |__| For Process Research |__| For Calibration

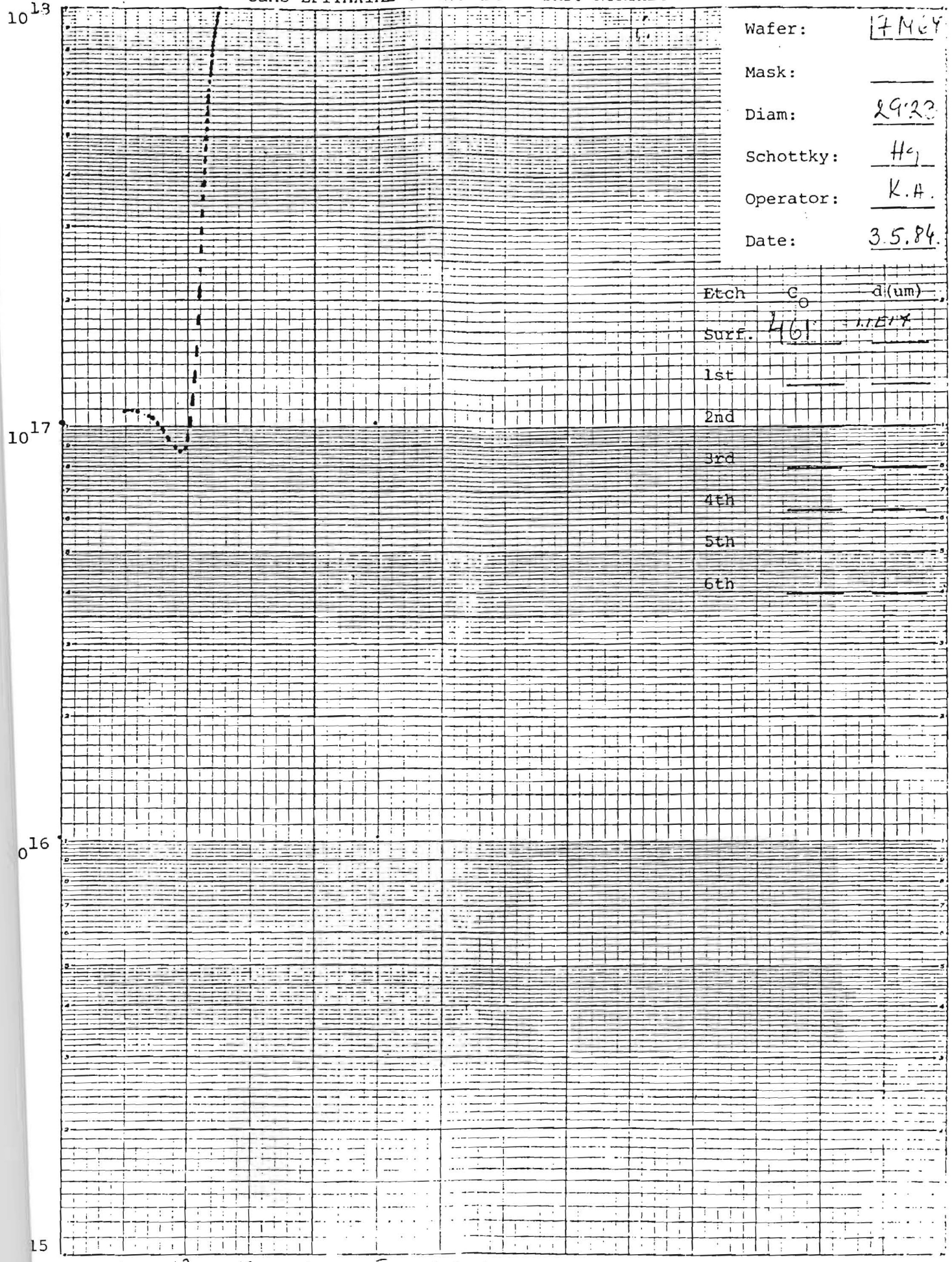
|__| For Sample Purposes Other _____

unt Ordered _____ Amount Delivered _____

_____ Date: _____

Figure 3

GaAs EPITAXIAL GROWTH LAB - SMDO NORTHBORO




Wafer: 1746

Mask:

Diam: 2.92

Schottky: Hg

Operator: K.A.

Date: 3.5.84

| Etch | $C_o$ | d(um) |
|---|---|---|
| Surf. | 461 | 1.1E17 |
| 1st | | |
| 2nd | | |
| 3rd | | |
| 4th | | |
| 5th | | |
| 6th | | |

A-3648

Del No. 8

Status Report No. 8

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 April 1984 through 30 April 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The program activity during this reporting period has been slowed down while awaiting new supplies of chemicals and gases.

## GENERAL

A severe problem regarding the photoresist adhesion has not been solved however steps have been taken to replace all of the process chemicals and gases. There have been numerous experiments conducted in a effort to determine the cause of the poor adhesion. There has been no past instance in which this adhesion problem has been so severe.

## PLANS FOR NEXT MONTH

- Solve the adhesion problem.

A 3648

Del No. 9

Status Report No. 9

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 May 1984 through 31 May 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The program is once again on track. The photoresist adhesion problem has been solved. A wafer section has successfully been processed. The diode characteristics are excellent.

## GENERAL

Success has finally been realized following several weeks of experimentation trying to solve the photoresist adhesion problem. The problem was not with the $SiO_2$ deposition gases, photoresist or processes, but instead with one of the components of the $SiO_2$ etch solution; ammonium fluoride.

Having eliminated potential causes of poor adhesion with little success, it was decided to replace the etch solution; the problem was immediately solved. It still is not clear what was wrong with the ammonium fluoride solution. When mixed with the proper amount of HF and water, the solution behaved quite normally with the exception of causing the resist to lift with subsequent lateral etching of the $SiO_2$.

The diode process proceeded without further incident upon resolving the etch problem. Excellent diode characteristics have been realized from wafer GT17M63-2. The wafer has been mapped and scribed into chips. Some of this wafer section was used to step through the diode process to ensure a "go" for the main body of the wafer. Consequentially, a sorting process is presently underway in order to determine the number of good chips.

The dc test results indicate that the diodes from the

GT17M63-2 wafer are among the best thus far produced at Georgia Tech. Preliminary forward dc test data from the 4 diode diameters are shown in figure one. The reverse breakdown voltages are typically 9V @ 1 A.

Diode capacitance, RF, and heat stress tests will commence following the sorting process.

PLANS FOR NEXT MONTH

- Continue Tests

DIODE NUMBER 15. = 1.5u Dia.

IDEALITY FACTOR 1.09
RESISTANCE 12.03
SAT CURRENT 3.43-15

| CURRENT UA | VOLTAGE VOLTS |
|---|---|
| 0.010 | 0.430 |
| 0.100 | 0.487 |
| 1.000 | 0.552 |
| 10.000 | 0.616 |
| 100.000 | 0.683 |
| 1,000.000 | 0.766 |
| 3,160.000 | 0.838 |
| 10,000.000 | 0.946 |

DIODE NUMBER 20. = 2.0u Dia.

IDEALITY FACTOR 1.08
RESISTANCE 6.84
SAT CURRENT 7.16-15

| CURRENT UA | VOLTAGE VOLTS |
|---|---|
| 0.010 | 0.405 |
| 0.100 | 0.462 |
| 1.000 | 0.526 |
| 10.000 | 0.590 |
| 100.000 | 0.656 |
| 1,000.000 | 0.735 |
| 3,160.000 | 0.794 |
| 10,000.000 | 0.866 |

DIODE NUMBER 30. = 3.0u Dia.

IDEALITY FACTOR 1.07
RESISTANCE 2.30
SAT CURRENT 4.38-15

| CURRENT UA | VOLTAGE VOLTS |
|---|---|
| 0.010 | 0.415 |
| 0.100 | 0.471 |
| 1.000 | 0.535 |
| 10.000 | 0.599 |
| 100.000 | 0.663 |
| 1,000.000 | 0.734 |
| 3,160.000 | 0.778 |
| 10,000.000 | 0.827 |

DIODE NUMBER 50. = 5.0u Dia

IDEALITY FACTOR 1.10
RESISTANCE 0.92
SAT CURRENT 1.88-14

| CURRENT UA | VOLTAGE VOLTS |
|---|---|
| 0.010 | 0.380 |
| 0.100 | 0.439 |
| 1.000 | 0.505 |
| 10.000 | 0.570 |
| 100.000 | 0.635 |
| 1,000.000 | 0.704 |
| 3,160.000 | 0.746 |
| 10,000.000 | 0.788 |

Figure 1. Forward Biased Diode dc Test Data, GT17M63-2.

A-3648

Del No. 10

Status Report No. 10

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 June 1984 through 30 June 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

INTRODUCTION

The wafer run number GT17M63-2 is presently under evaluation. Some of the diodes have been packaged and are undergoing heat stress testing.

GENERAL

The wafer has been scribed and separated into chip form. The individual chips have been screened for mechanical defects. There are a sufficient number of chips (1000) to fill the program requirements for testing and deliverables. The cosmetic failures can be included in the final shipment for use as experimental devices.

HEAT STRESS TEST

The first lot of five diodes has been heat stressed under bias for 191.5 hours. Diode behavior is similar to that experienced on previous Phase II diodes. After 125 hours, one of the test diodes (number two) was damaged by handling and subsequent failure rapidly ensued. The remaining four diodes ran for 191.5 hours, at which time the test was terminated. The test data summary is contained in Figures 1 and 2.

A second lot of five diodes was placed on heat stress. The temperature was increased to 350°C for this test in order to obtain failure in a shorter time period. The results of this test series will be included in the next monthly status letter (July).

PLANS FOR NEXT MONTH

- Continue diodes tests.

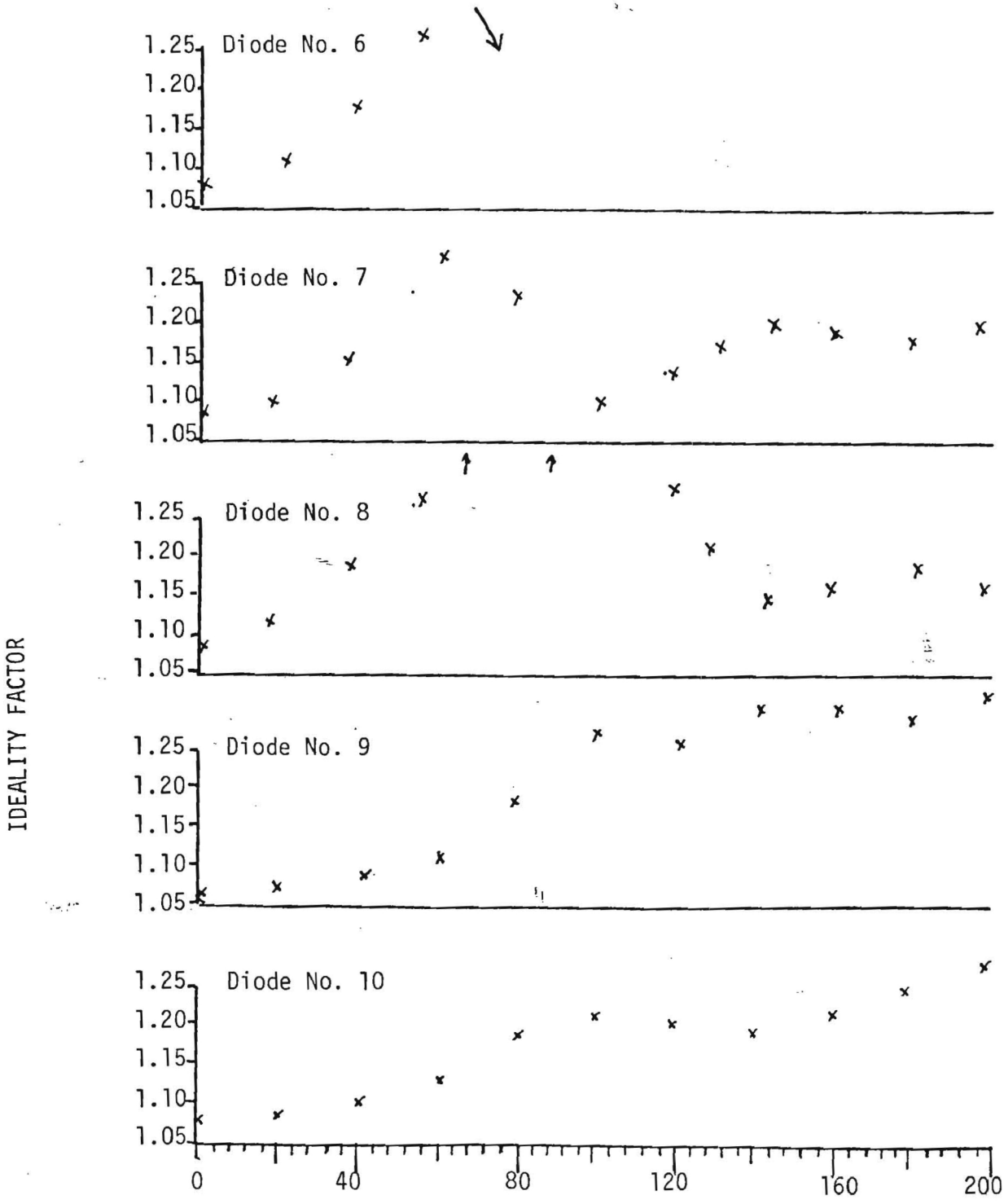
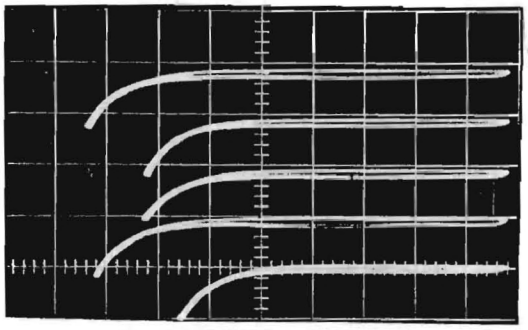
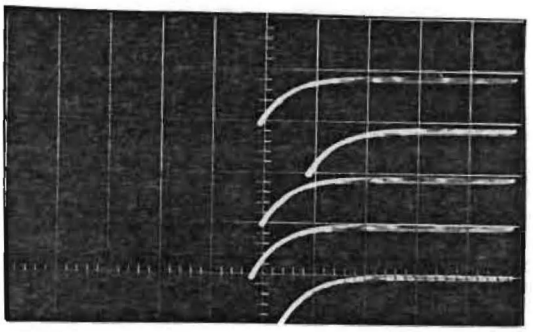


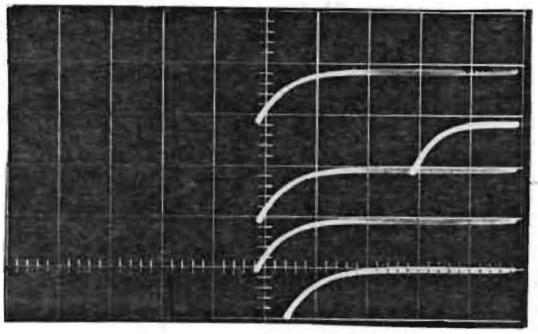

Figure 1. Cross Gemoetry, GT17M63-2, Ideality Factor vs Time 350°C.

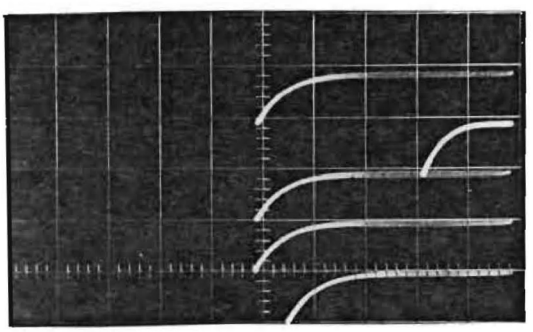
"  T = +4.7 Hrs



"  T + 119.5 Hrs.



"  T + 143.5 Hrs.



"  T + 191.5 Hrs.

Figure 2. Cross Geometry GT17M63-2, change in room temp reverse breakdown vs hours @ 330°C.

A-3648

Del No. 11

Status Report No. 11

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 July 1984 through 31 July 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

The diode evaluation is continuing. The test results thus far obtained indicate that the GT17M63-2 run is acceptable for delivery. Packaging following final dc testing is being readied.

## GENERAL

The GT17M63-2 diode dc performance is good. The heat stress data indicate that a long life can be expected from these diodes. RF testing has not been performed to date; however, these tests are scheduled and awaiting mixer sharpless wafer assembly. Employee vacation and equipment scheduling has delayed the start of these assemblies and test.

## CAPACITANCE MEASUREMENTS

Ten chips were selected at random and tested to determine the diode zero volt capacitances. The four diode sizes were measured utilizing a Boonton 75D capacitance bridge. The capacitance values are listed in table 1. These values are approximately one percent higher in capacitance than the diodes produced during phase two; they are, however, well within the requirements.

## HEAT STRESS TESTS

High temperature tests (350$^{o}$C) have been conducted on five new chips (6-10) during this report period. Further tests on five additional diodes (11-15) are being planned at 330$^{o}$C, with a scheduled increase in temp to 350$^{o}$C if diodes (11-15) remain within specification. This latter test will commence in August.

| | Diode Dia microns | | | | |
|---|---|---|---|---|---|
| | 1.5 | 2.0 | 3.0 | 5.0 | |
| 1 | 4.84 | 7.00 | 13.49 | 30.11 | |
| 2 | 3.15 | 6.94 | 13.20 | 28.84 | |
| 3 | 5.20 | 7.73 | 13.25 | 31.75 | |
| 4 | 3.94 | 7.21 | 14.45 | 32.12 | capacitance |
| 5 | 4.33 | 6.42 | 14.04 | 31.06 | $F_{fds}$ |
| 6 | 4.15 | 7.31 | 13.62 | 31.25 | |
| 7 | 3.90 | 6.81 | 13.50 | 31.22 | |
| 8 | 3.92 | 6.52 | 13.24 | 30.08 | |
| 9 | 3.85 | 6.87 | 13.26 | 30.02 | |
| 10 | 3.89 | 6.92 | 13.35 | 31.14 | |
| Avg. $C_j(o)$ | 4.16 | 6.97 | 13.54 | 30.76 | |

Table 1. Diode Capacitance vs Diode Dia.

Typical of diodes tested during phase two, the ideality factor on diodes (6-10) increased rather sharply after a few hours at 350°C. Two of the diodes, 9 and 10, remained in spec. for 80 and 70 hours respectively. These data and $V_B$ for diodes (6-10) are shown in figures 1 and 2.

PLANS FOR NEXT MONTH

- Continue Diode Testing

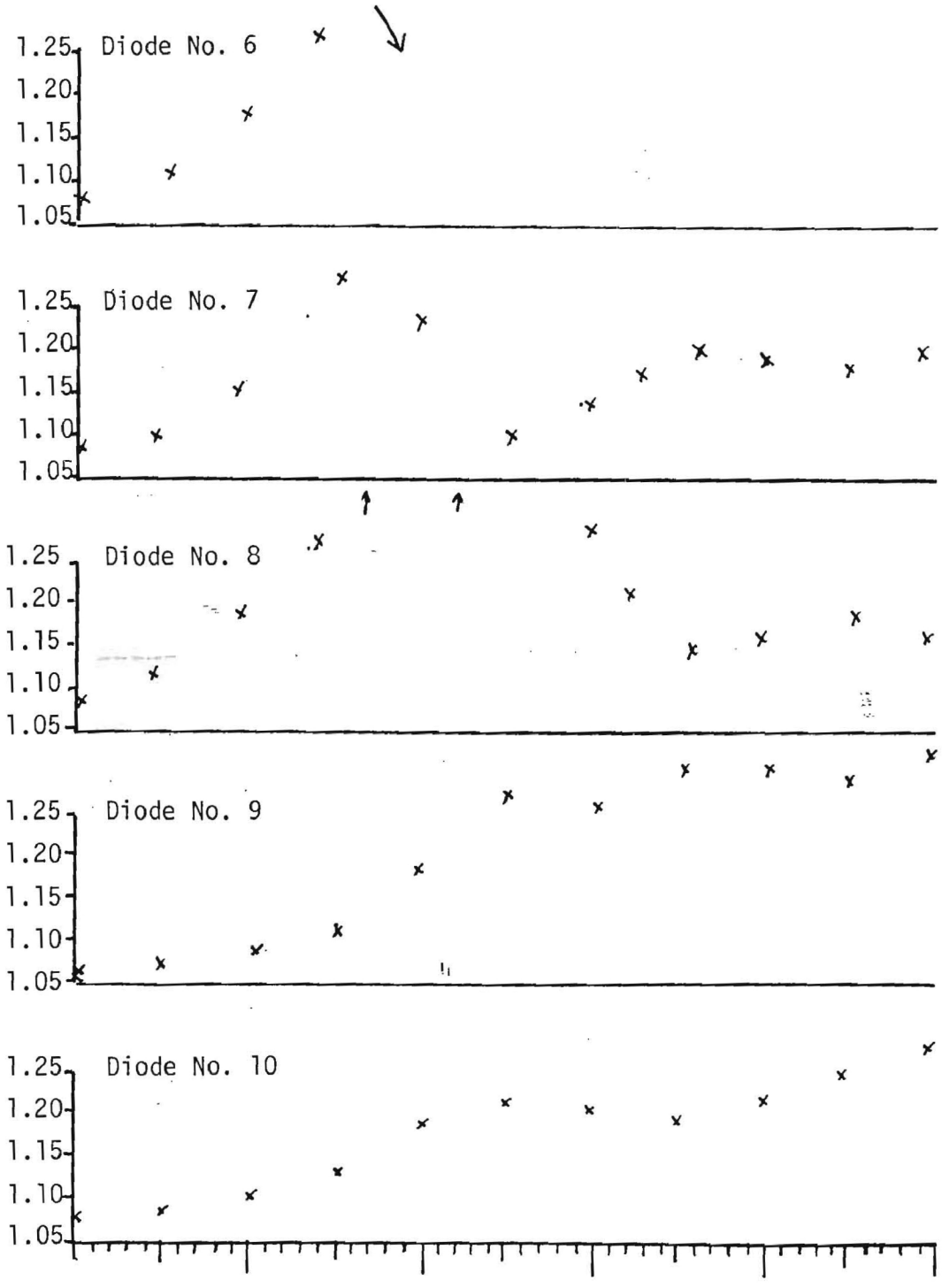
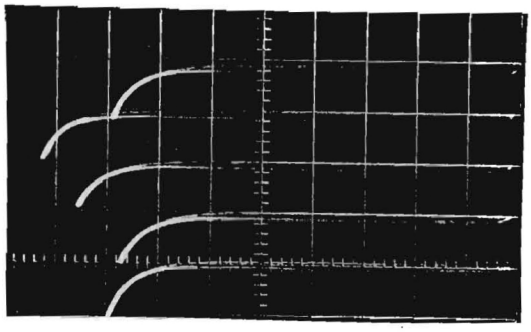



Figure 1. Cross Gemoetry, GT17M63-2, Ideality Factor vs Time 350°C.

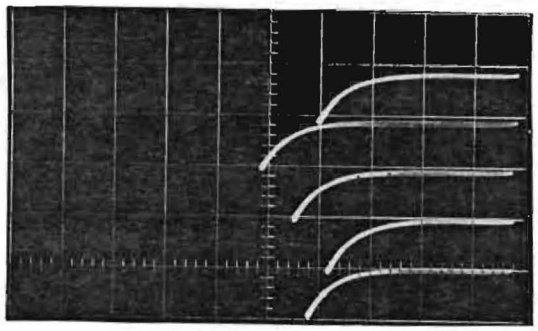


Diode Number

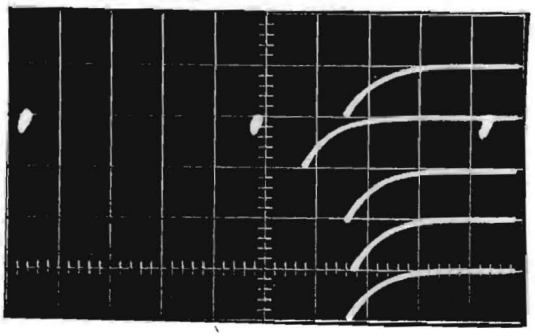
--- 6
--- 7
--- 8
--- 9
--- 10

Scale

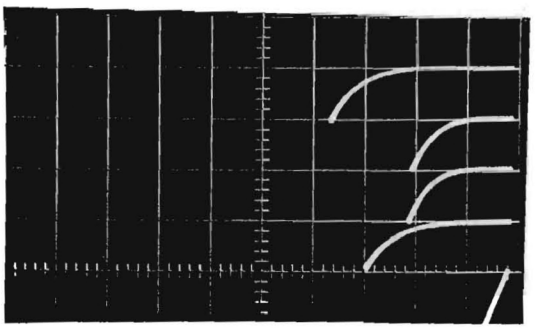
Vert = 0.01 mA/DIV
Horiz = 1.0V/DIV



" T = 71.5 Hrs.



" T = 167.5 Hrs.



" T = 263.5 Hrs.

Figure 2. Cross Geometry GT17M63-2, change in room temp. reverse breakdown vs hours @ 350°C.

A-3648

Del No. 12

Status Report No. 12

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 August 1984 through 31 August 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

INTRODUCTION

The diode program is nearly completed. All of the required heat stress tests have been accomplished. The diodes are presently undergoing final dc test and are being packaged for delivery.

GENERAL

The third lot of diodes (11-15) mentioned in status letter number 11 have been subjected to heat stress.

Conflicts in scheduling are delaying the RF test; however, relying on past experience, we anticipate that good dc data implies acceptable Rf performance.

HEAT STRESS TEST

Diodes (11-15) have performed as expected. The 5 diodes under test at 330°C, remained within specification for as long as 380 hours, at which time the temperature was increased to 350°C. Within a few hours to as many as 50 hours the diodes all exceeded specification limits. These data are shown in figures one and two. The data indicate that a metalurgical reaction commences rapidly at a critical temperature between 330°C and 350°C. This same reaction was observed during phase two which indicates that the process recipe is repeatable.

DELIVERABLES

The diodes are being packaged for delivery. One shipping container is on hand and a second is on order from ZERO manufacturing company but not yet received.

PLANS FOR NEXT MONTH

- Complete diode tests
- Ready diodes for delivery.

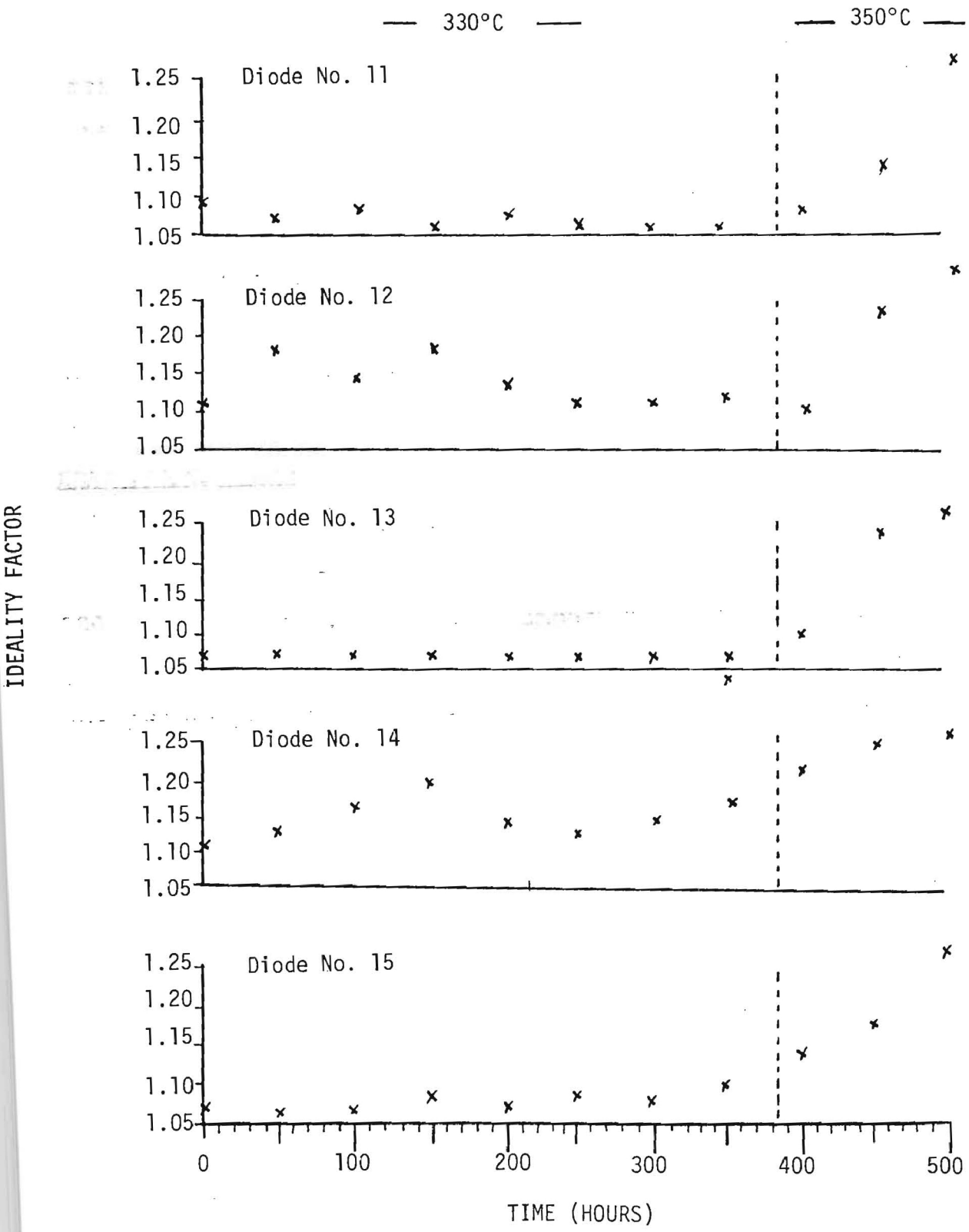
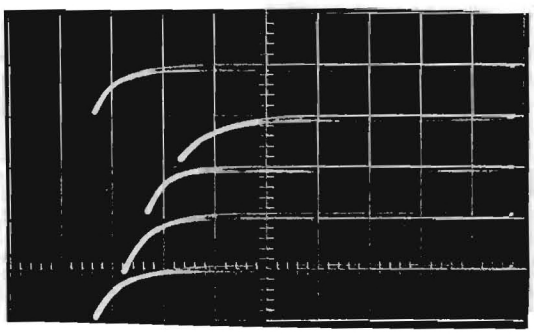
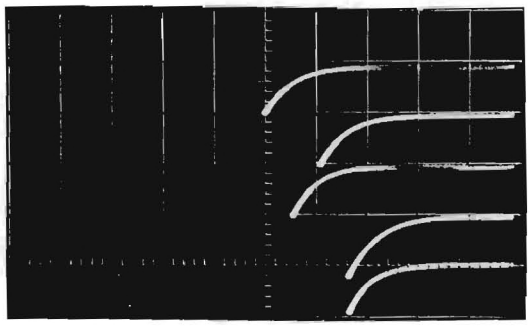


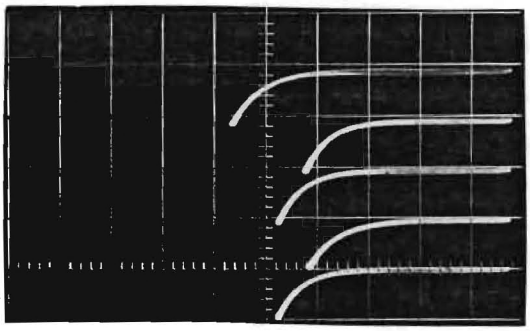

Figure 1. Cross Geometry GT17M63-2, Ideality Factor vs Time 330°C with increase to 350°C.



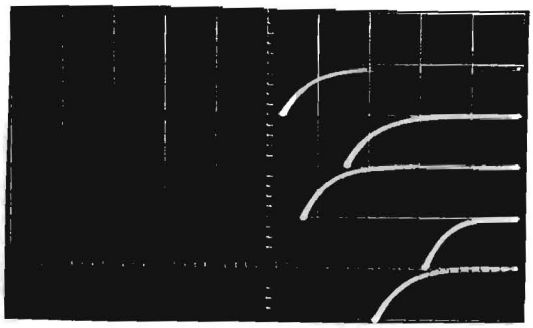

T = 0 hrs 330°C



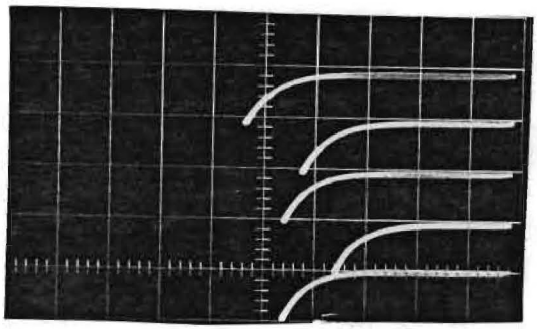
T = 384 Hrs 350°C



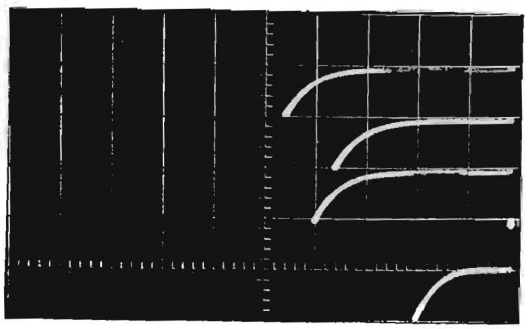
T = 144 Hrs 330°C



T = 456 Hrs 350°C



T = 216 Hrs 330°C



T = 504 Hrs 350°C

Scale

Vert = 0.01 mA/DIV
Horiz = 1.0V/DIV

Figure 2. Cross Geometry GT17M63-2, change in room temp. reverse breakdown vs hours @ 330°C with increase to 350°C.

A-3648

Del No. 13

Status Report No. 13

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
1 September 1984 through 30 September 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Engineering Experiment Station
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

INTRODUCTION

The diode program is completed except for the Rf tests, final diode delivery and program wrapup. Rf testing should be completed before the October 27th program expiration date.

GENERAL

The diode packaging is completed. 800 diodes from Run GT17M63-2 have been tested and packaged for delivery. Approximately 200 additional diodes which failed cosmetically are available for use as engineering models. These additional diodes will be packaged in 100 chip trays and labeled untested. The dc test yield is nearly 100 percent; therefore, the engineering models should be representative of the tested lot.

TEST FIXTURES AND RESIDUAL MATERIALS

The heat stress station and residual Gallium Arsenide material will be retained by Georgia Tech until otherwise instructed by Bernie Walsh of Hughes Aircraft Company.

Del No. 15

# FINAL DOCUMENTATION

# MILLIMETER WAVE MIXER DIODES - PHASE III

Contract period covered
7 September 1983 through 27 October 1984
P.O. No. S8-893512-LJS

A-3648

Submitted to
Hughes Aircraft Company
El Segundo, California 90245

by

G. N. Hill

Physical Sciences Division
Electromagnetics Laboratory
Georgia Tech Research Institute
Atlanta, Georgia 30332

Contracting through
Georgia Tech Research Corporation
Georgia Institute of Technology
Atlanta, Georgia 30332

## INTRODUCTION

This report provides the final documentation of the work performed on contract P.O. S8-893512-LJS line item 8 with Hughes Aircraft Co. El Segundo, California.

Included in this report are the diode process recipe, process run log and data associated with the deliverable diodes, Georgia Tech/GTRI diode wafer run number GT17M63-2.

These diodes were fabricated in accordance with Hughes drawing specification number HAC 3414270 Rev(C). One thousand diode chips were delivered, eight hundred of which were dc tested. Two hundred diodes were untested and delivered as engineering samples.

## GENERAL

### Diode dc Tests

Upon completion of the wafer process but before scribing, 3 micron diameter diodes in several areas of the wafer were whisker probed in order to determine diode uniformity and quality. The diodes were tested for diode ideality, $\eta$ , series resistance, $R_S$ and reverse voltage breakdown, $V_b$. The average values for 13 diodes tested were; $\eta = 1.10$, $R_S = 3.74\Omega$ , $V_B = 9.19V$. These data are also contained in the diode map section of the Process Checklist. Diode junction capacitance was obtained following scribing of the wafer into chip form. These diodes were attached to a metal substrate to facilitate handling and then measured. The capacitance data on the four diode sizes is contained in table one. Utilizing the average values for capacitance and series resistance, a cutoff frequency of 3.14 THz is obtained for

the 3 micron diode.

| | Diode Diameter Microns | | | | |
|---|---|---|---|---|---|
| Diode Number | 1.5 | 2.0 | 3.0 | 5.0 | |
| 1 | 4.84 | 7.00 | 13.49 | 30.11 | |
| 2 | 3.15 | 6.94 | 13.20 | 28.84 | |
| 3 | 5.20 | 7.73 | 13.25 | 31.75 | |
| 4 | 3.94 | 7.21 | 14.45 | 32.12 | Capacitance |
| 5 | 4.33 | 6.42 | 14.04 | 31.06 | < FFds |
| 6 | 4.15 | 7.31 | 13.62 | 31.25 | |
| 7 | 3.90 | 6.81 | 13.50 | 31.22 | |
| 8 | 3.92 | 6.52 | 13.24 | 30.08 | |
| 9 | 3.85 | 6.87 | 13.26 | 30.02 | |
| 10 | 3.89 | 6.92 | 13.35 | 31.14 | |
| | --- | --- | --- | --- | |
| Avg. $C_J(0v)$ | 4.16 | 6.97 | 13.54 | 30.76 | |

Table 1. Diode Capacitance vs Diode Diameter.

All of the specifications have been met by a wide margin, the specified values and those that were achieved are shown in table two.

| HAC3414270RevC | GT17M63-2 |
|---|---|
| Specification | Actual |
| $\eta$ < 1.2 | 1.10 |
| $R_S$ < 7 ohms | 3.74 ohms |
| $V_B$ > 3 volts | 9.19 volts |
| $f_C$ > 1.3 TH2 | 3.14 TH2 |

Table 2. DC Test Data, Requirements versus Achieved.

Heat Stress Test

Sample diodes chips were selected at random and subjected to thermal stress of 330°C and 350°C. It was determined from previous experience that lower temperatures (300°C) would not deteriorate the diodes in a reasonable time period. Fifteen diodes were mounted in conventional diode packages. Thermocompression wire bonds were made to the diode cross geometry on each chip. DC measurements were performed at room temperature in determining the forward and reverse characteristics prior to thermal cycling. The diodes were then installed into the thermal stress test fixture and forward biased at 30 mA. The diodes were removed from the test fixture daily and the room temperature data again recorded. The first five diodes survived 330°C for approximately 220 hours before the test was terminated. All of the diodes remained within specifications with the exception of number two which was damaged in handling. These data are contained in figures 1 and 2.

Five new diodes (6-10) were installed and the test

temperature increased to 350°C in order to obtain failures in a shorter time period. Diode numbers 6,7 and 8 degraded rapidly and after 40 hours were out of specification. Diodes 9 and 10 survived for approximately 80 hours. These data are shown in figures 3 and 4.

Diodes 11 thru 15 were next installed and stressed At 330°C for 384 hours. All of the diodes demonstrated some change in $V_B$; however, the ideality factors remained well within specification.

The temperature was increased at this point to 350°C. Degradation ensued in a manner similar to diodes 6 thru 10. These data, diodes 11-15 are shown in figures 5 and 6.

SUMMARY

All of the test data show that the GT17M63-2 wafer run was acceptable for delivery. Each diode chip was tested, boxed and serialized, the dc test data were recorded and supplied both on the computer printout and each diode box.

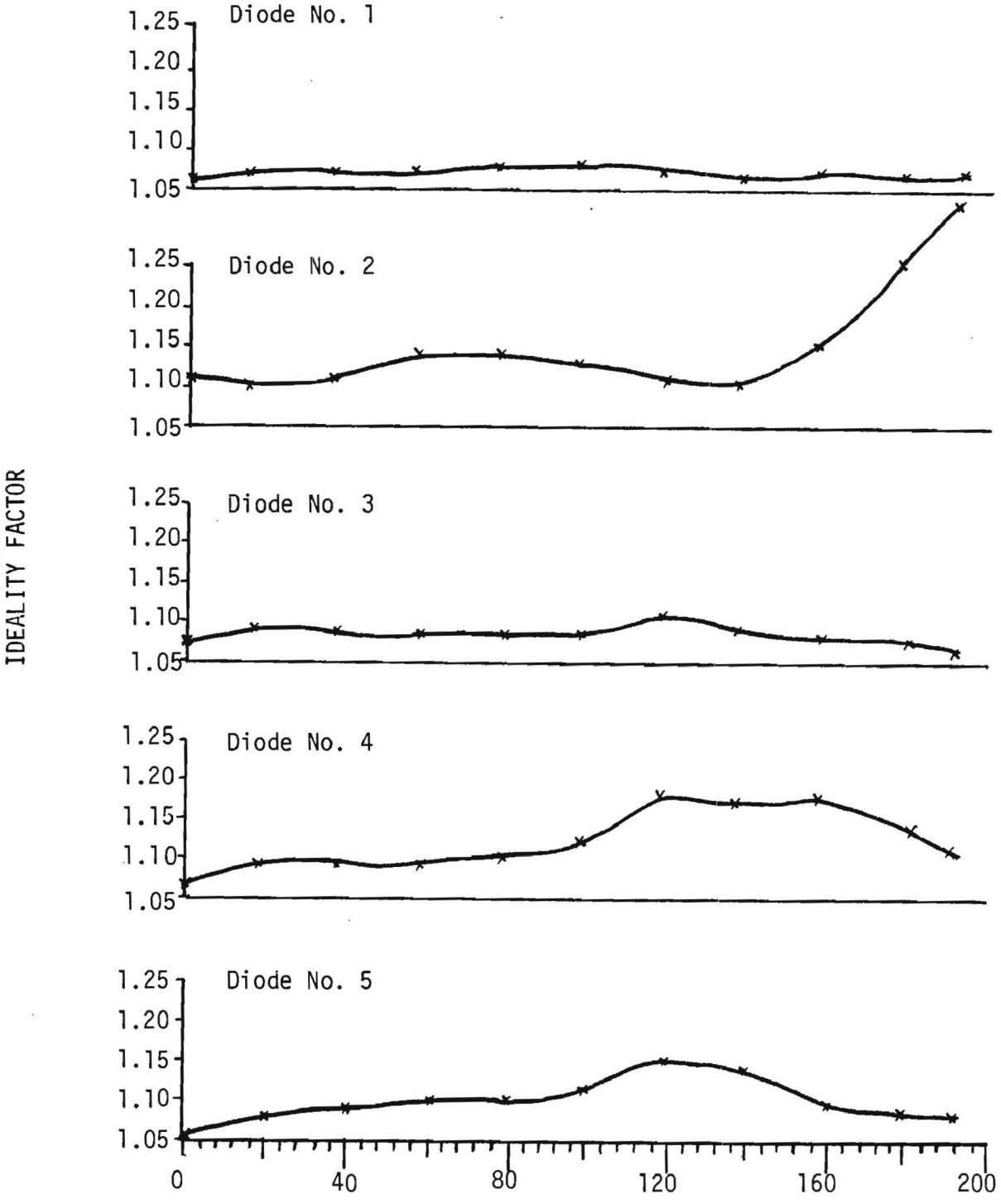
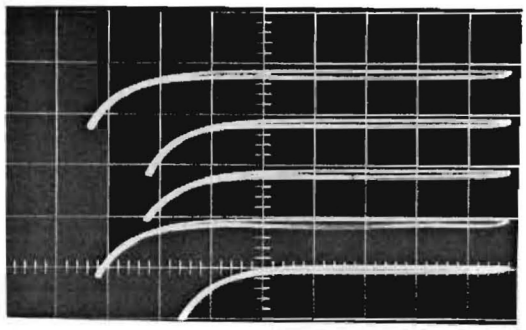
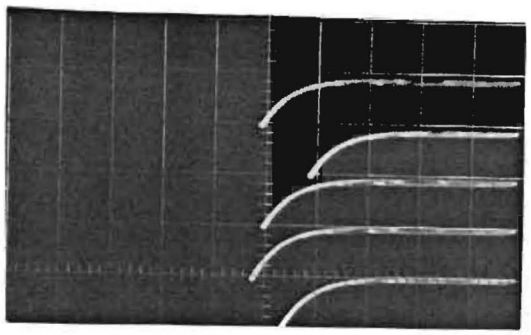


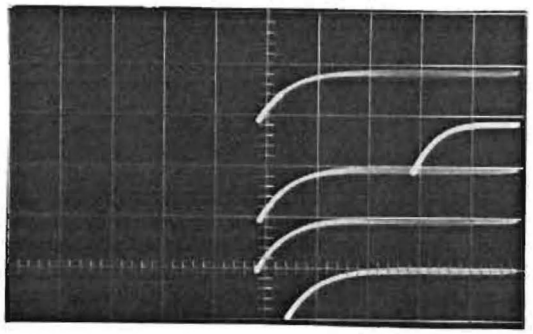

Figure 1. Cross Geometry, GT17M63-2, Ideality Factor vs Time @ 330°C.

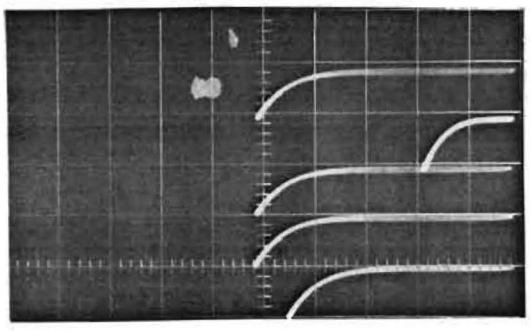
"  T = +4.7 Hrs



"  T + 119.5 Hrs.



"  T + 143.5 Hrs.



"  T + 191.5 Hrs.

Figure 2. Cross Geometry GT17M63-2, change in room temp reverse breakdown vs hours @ 330°C.

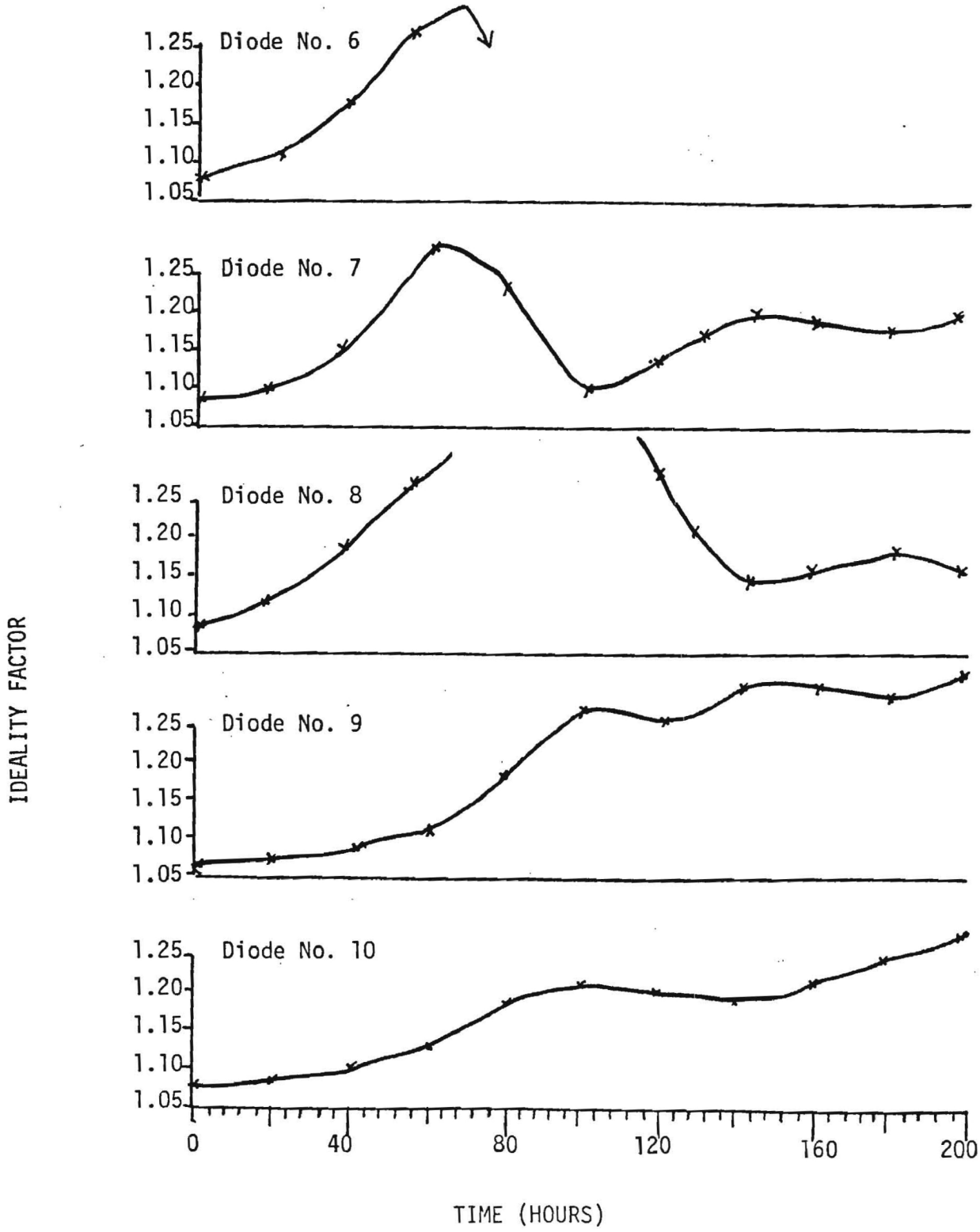
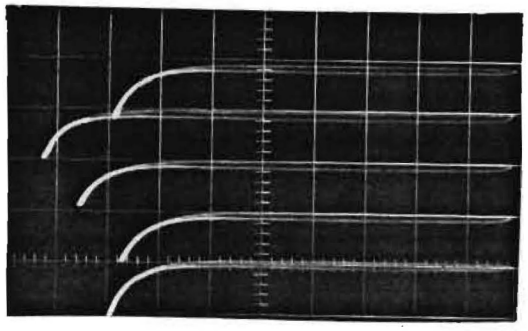



Figure 3. Cross Geometry, GT17M63-2, Ideality Factor vs Time @ 350°C.

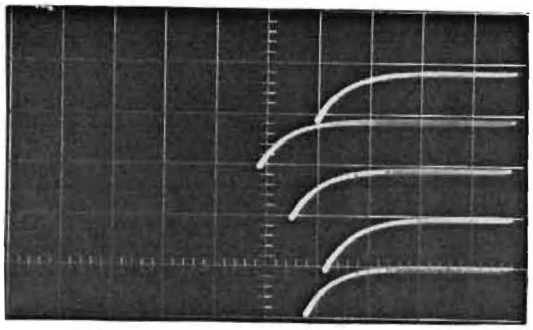


Diode Number

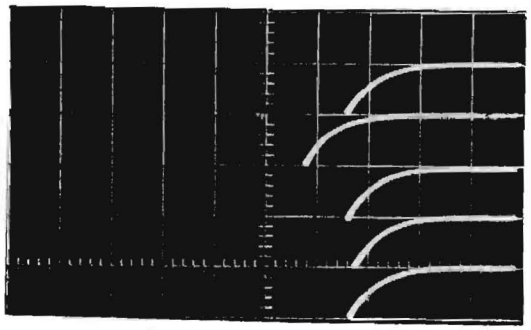
--- 6
--- 7
--- 8
--- 9
--- 10

Scale

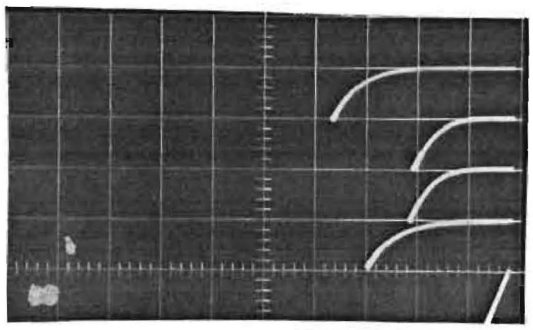
Vert = 0.01 mA/DIV
Horiz = 1.0V/DIV



" T = 71.5 Hrs.



" T = 167.5 Hrs.



" T = 263.5 Hrs.

Figure 4. Cross Geometry GT17M63-2, change in room temp. reverse breakdown vs hours @ 350°C.

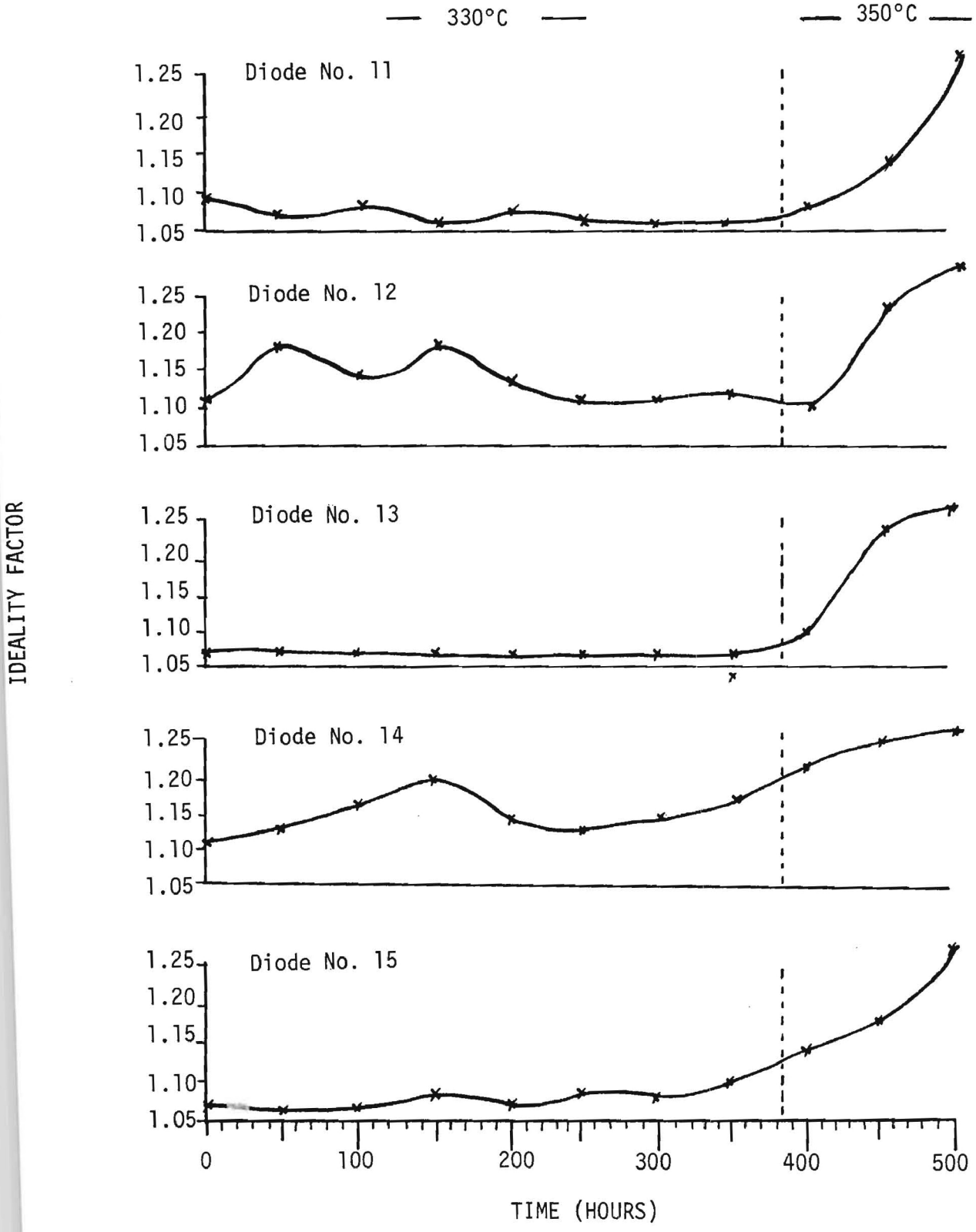
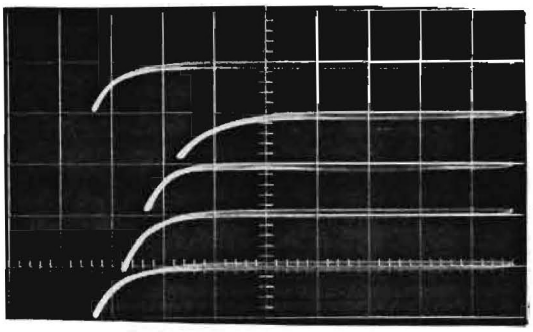
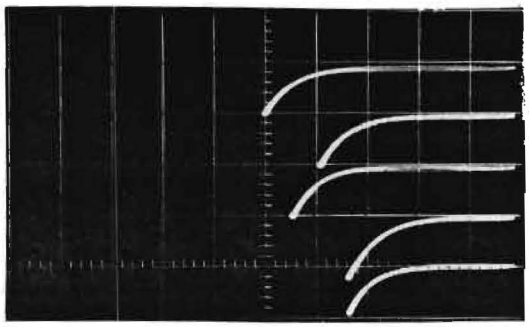


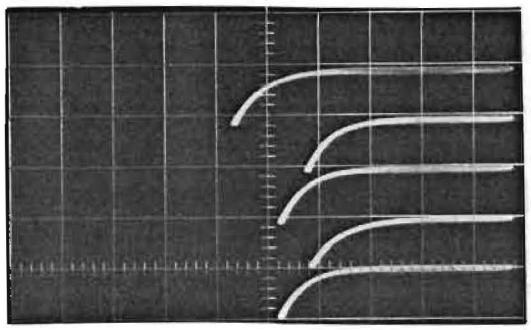

Figure 5. Cross Geometry GT17M63-2, Ideality Factor vs Time @ 330°C with increase to 350°C.



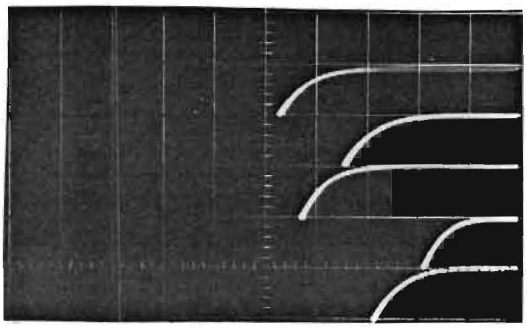

T = 0 hrs 330°C



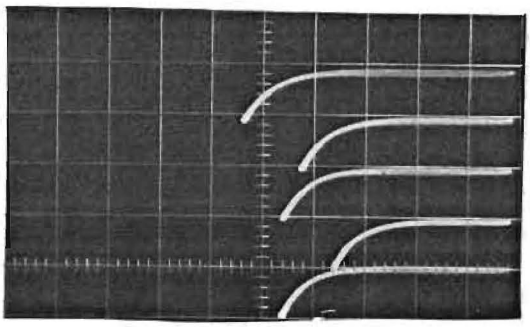
T = 384 Hrs 350°C



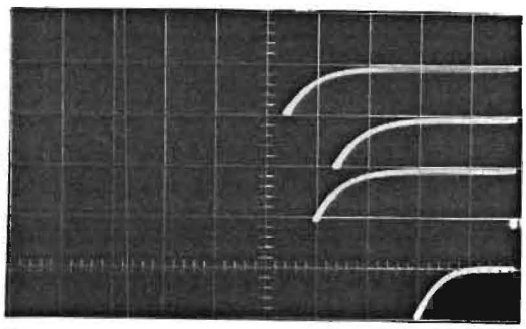
T = 144 Hrs 330°C



T = 456 Hrs 350°C



T = 216 Hrs 330°C



T = 504 Hrs 350°C

Scale

Vert = 0.01 mA/DIV
Horiz = 1.0V/DIV

Figure 6. Cross Geometry GT17M63-2, change in room temp. reverse breakdown vs hours @ 330°C with increase to 350°C.

# APPENDIX

PROCESS CHECKLIST

Millimeter Wave Mixer Diode

Hughes 3414270 Rev. (C)

WAFER PROCESS RUN NUMBER: GT17M63-2

DATE: 3-12-84

STAFF: G.N. Hill

PI-1 GaAs MATERIALS SPEC.

Attached Copy yes ✓ no ____

Haze ____ Hillock ____ Cracks ____ Other ____

Comments: Few scratched areas near edge. scribed around them in order to obtain best area.

PI-2 WAFER CLEAN-UP

Process Complete yes ✓ no ____

Inspect - Pass yes ✓ no ____

Comments: Good cleanup 1st time
No visible contamination

PI-3 OXIDE GROWTH

Temp 330 °C

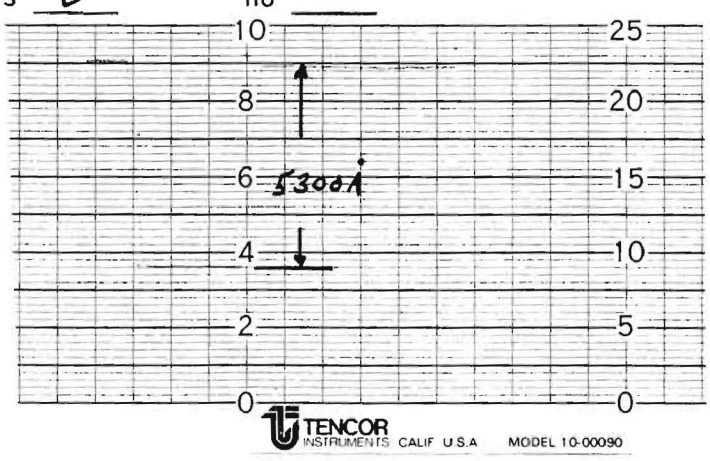
Flow $N_2$ 12.5 $O_2$ 6.5 $SiH_4$ 4/6 flow meter settings

Growth Time 7.1 min

$SiO_2$ Thickness 5300 Å. Color Pink Blue

Step Profile Attached yes ✓ no ____

Comments: NONE



PI-4 DIODE GEOMETRY POSITIVE LITHOGRAPHY

Spin Speed 6K rpm

Time 25 secs

Pre Expose Bake Temp. 95 °C Time 25 min.

Expose 4 secs

Develop 45 secs

Inspect - Pass yes ✓ no ____

Postbake Temp 110 °C Time 10 min.

Comments: NONE

PI-5 OXIDE ETCH AND RESIST STRIP BACK

Etch 1. Time 35 secs Color Tan Blue

Etch 2. Time 5 secs Color Light Tan

Etch 3. Time 2 secs Color clear

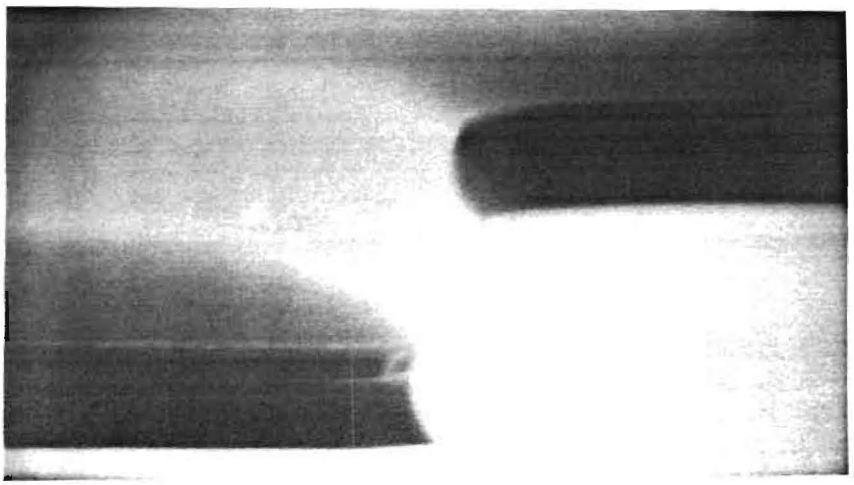
Vacuum Bake Temp 150 °C Time 30 min.

Plasma Etch Time 5 min.

Inspect - SEM Pass yes ✓ no ____

Comments:
NONE

Photoresist Thickness



PI-6 ·DEPOSIT TRI-METAL

Etch Temp 22 °C Time 30 secs

E-Beam System pressure < $10^{-9}$ Torr 26 hrs.

Titanium - power .7 KW, Monitor Res. 44 ohms

Platinum - power 1.5 KW, Monitor Res. 31 ohms

Gold - power .6 KW, Monitor Res. 1.3 ohms

Inspect - Metal Thicknesses

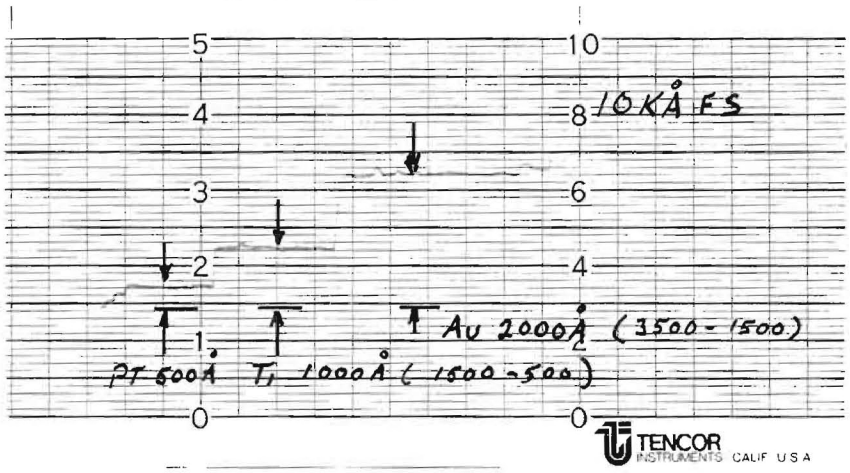
Ti 1000 Å Step Profile yes ✓ no ____

PT 500 Å

Au 2000 Å

SEM Photo Attached

Comments: NONE

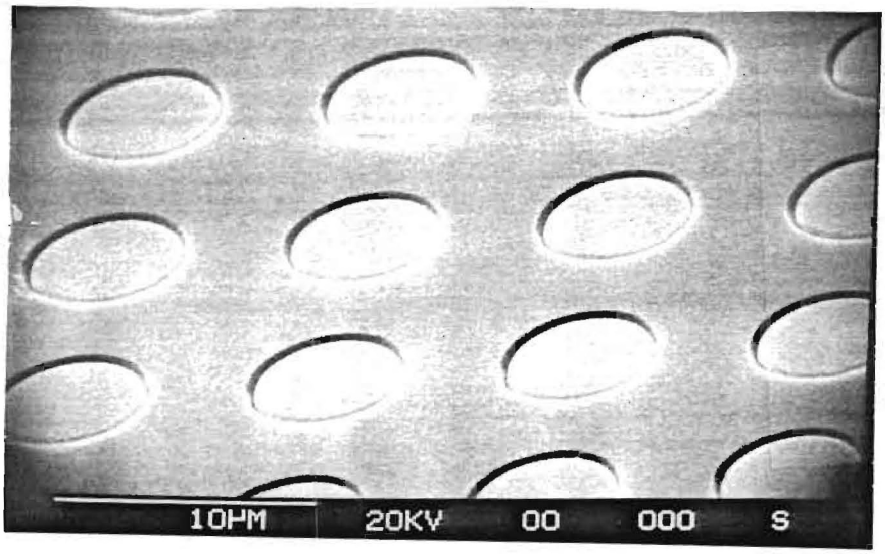



PI-7 LIFTOFF

SEM Photo Attached yes ✓ no ____

Comments:

Good,
Liftoff
No Problem



PI-8 WAFER THIN DOWN

Wafer Thicknesses Start _____ mm 16.3 mils

After Lap _____ mm 4.4 mils

After Polish _____ mm 2.2 mils

Inspect - Pass yes ✓ no ____

Comments: NONE

PI-9 METALLIZE CATHODE

Evaporator Pressure 3 x 10⁻⁷ torr

Alloy Contact, Temp °C 375 Time 3 min

Sputter Ti, Pt, Au

Ti 1100 Å

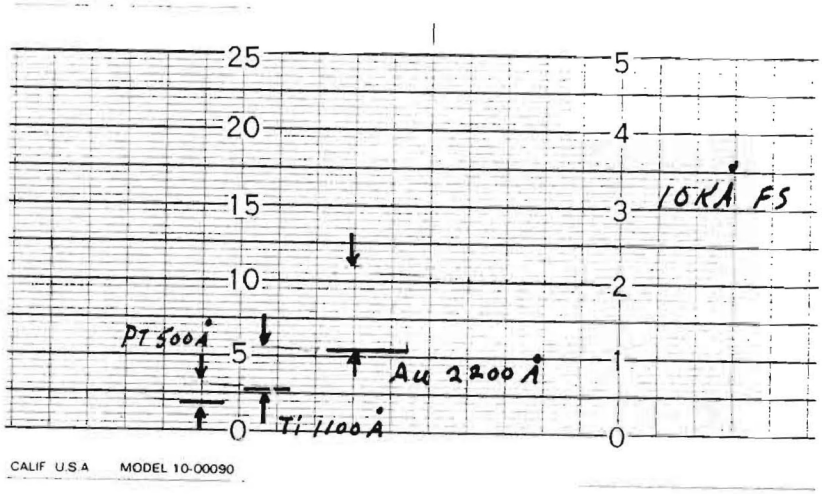
Pt 500 Å

Au 2200 Å

SEM Photo Attached

Comments: NONE

Step Profile yes ✓ no ____



PI-10 DC TEST

Wafer Map Attached yes ✓ no ____

Comments: Wafer is OK To scribe
~1100 chips Available
Need 900 chips min.

PI-11 WAFER SCRIBE AND BREAK

Completed yes ✓ no ____

Comments: Some incompted Breaks - save for
Extra chips To Huanes,

RAYTHEON
-9083(3/83)

## QUALITY ASSURANCE

GaAs Epitaxial Wafer NUMBER 17M63

FET Type Devices |__| Low Noise |__| Power |__| Other _____

With |__| Buffer |__| Contact Layer

IMPATT Type Devices |__| Flat Profile |__| Read Profile |__| Other _____

|Single Drift |__|Double Drift with |__|Thick Buffer |__|Standard Buffer |__|p** contact

tomer _____ Customer Order No. _____

_____ Spec. No. Georgia Tech. 17-1

ention _____ Memo No. _____

s Order No. _____ RAMAC No. _____

### SUBSTRATE

plier Sumitomo Electric Crystal Boule No. EX-1720-1 Slice No. 14

ntation 2° off 100 toward 110 Pregrowth Thickness 432 um

ier Concentration: _____ $10^{18}$ $cm^{-3}$ Dopant: Silicon.

stivity** _____

### ELECTRICAL CHARACTERISTICS

| Layer Type | Measured Carrier Concentration | Dopant | Thickness |
|---|---|---|---|
| Buffer | 72 x$10^{15}$ $cm^{-3}$ | Si | 5.5 um |
| Buffer | x10 $cm^{-3}$ | | um |
| Active | 11.0 x$10^{16}$ $cm^{-3}$ | Si | 0.22 um |
| Active | x$10^{16}$ $cm^{-3}$ | | um |
| Spike | x$10^{17}$ $cm^{-3}$ | | ( ) um |
| Contact | x10 $cm^{-3}$ | | ($x_p$) um |

### PHYSICAL CHARACTERISTICS

fer Size 5.1 cm Area 16 $cm^2$ Surface Morphology |__|

_____ x $10^{12}e^{-}$-$cm^{-2}$ $V_{knee}$ _____ volts (from Cvs V curve)

_____ x $10^{4}$pF-$cm^{-2}$ Interface _____ um/decade

### DELIVERY AUTHORIZATION

ivery authorized |__| to fill order |__| to fulfill contractual obligations

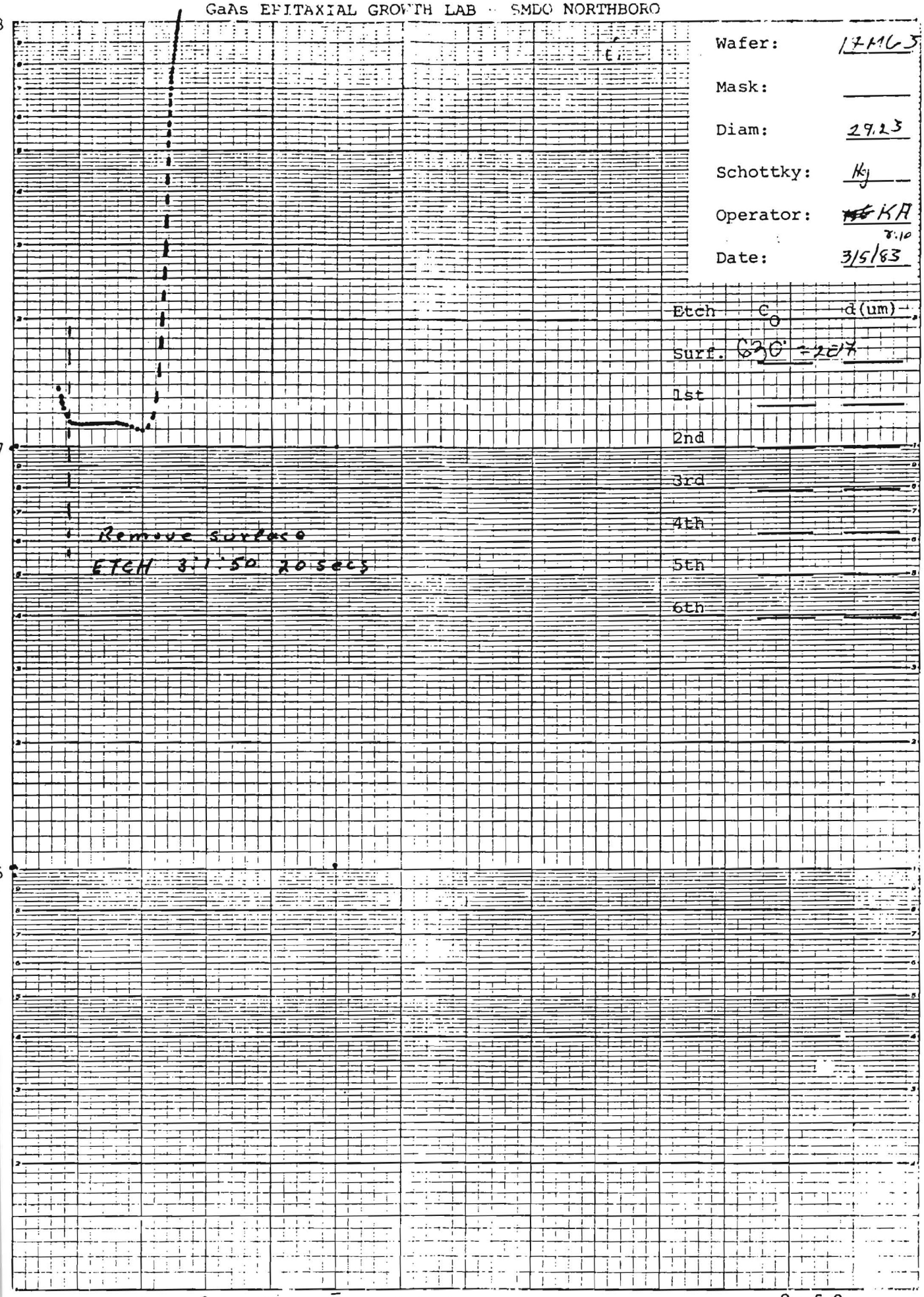
| For Device Research |__| For Process Research |__| For Calibration

| For Sample Purposes Other _____

unt Ordered _____ Amount Delivered _____

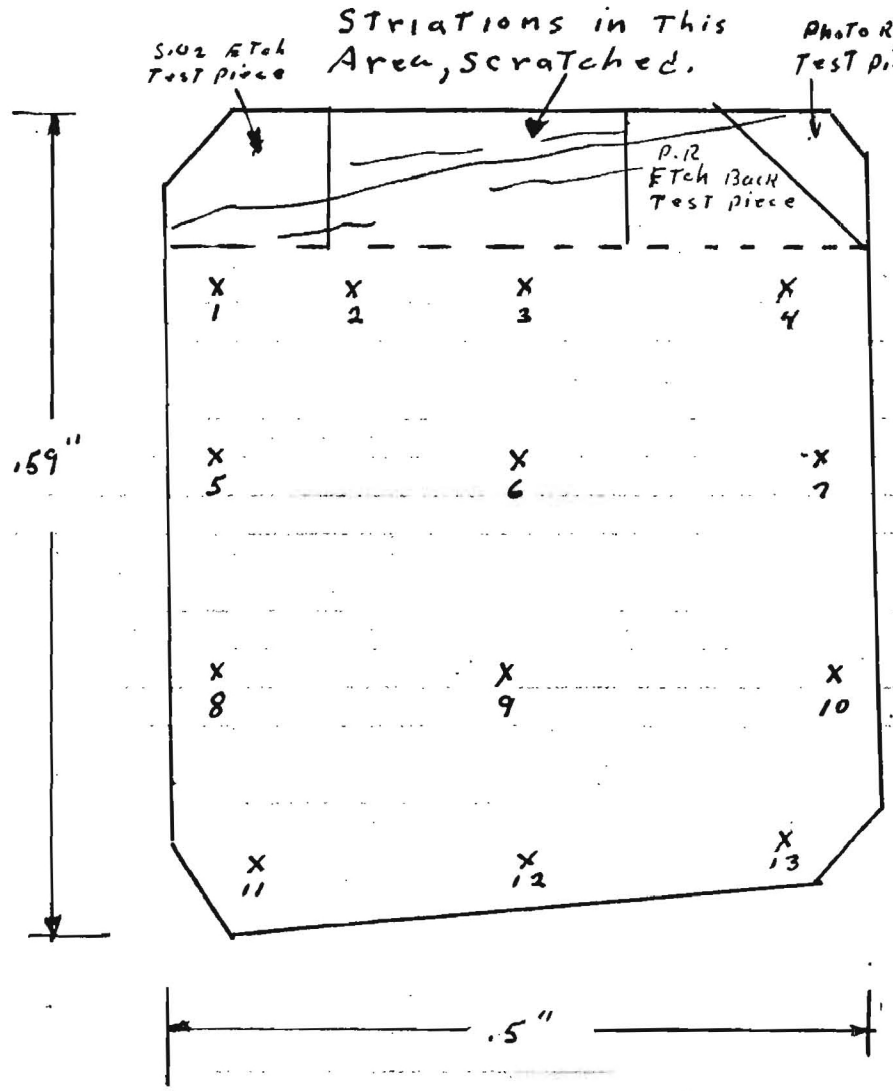
_____ Date: _____

GaAs EPITAXIAL GROWTH LAB - SMDO NORTHBORO



ES SKETCH PAD PROJECT A3648 BY G.N. Hill DATE 5-15-84

UNLESS OTHERWISE SPECIFIED
TOLERANCES – XX ± .01
XXX ± .005
FRAC. ± 1/32




Wafer Map

| Diode No | n | $R_s$ | $V_B$ |
|---|---|---|---|
| 1 | 1.08 | 3.57 | 9.6 |
| 2 | 1.08 | 3.85 | 9.2 |
| 3 | 1.08 | 4.14 | 9.1 |
| 4 | 1.10 | 3.77 | 9.5 |
| 5 | 1.14 | 3.61 | 9.5 |
| 6 | 1.11 | 4.26 | 9.5 |
| 7 | 1.09 | 3.63 | 9.0 |
| 8 | 1.10 | 4.19 | 9.7 |
| 9 | 1.11 | 3.06 | 9.0 |
| 10 | 1.09 | 3.46 | 10.0 |
| 11 | 1.08 | 3.65 | 8.6 |
| 12 | 1.09 | 3.88 | 9.1 |
| 13 | 1.14 | 3.51 | 9.3 |
| Avg | 1.10 | 3.74 | 9.19 |

Capacitance Data 3 micron Diodes

13.49
13.20
13.25
14.45
14.04
13.62
13.50
13.24
13.26
13.35
13.54

$$f_c = \frac{1}{2\pi R_s C_{J(0V)}}$$

$$f_c = 3.14\ T_{Hz}$$

yield, ~1100 chips

Wafer is Acceptable.

# PROCESS INSTRUCTIONS

FOR

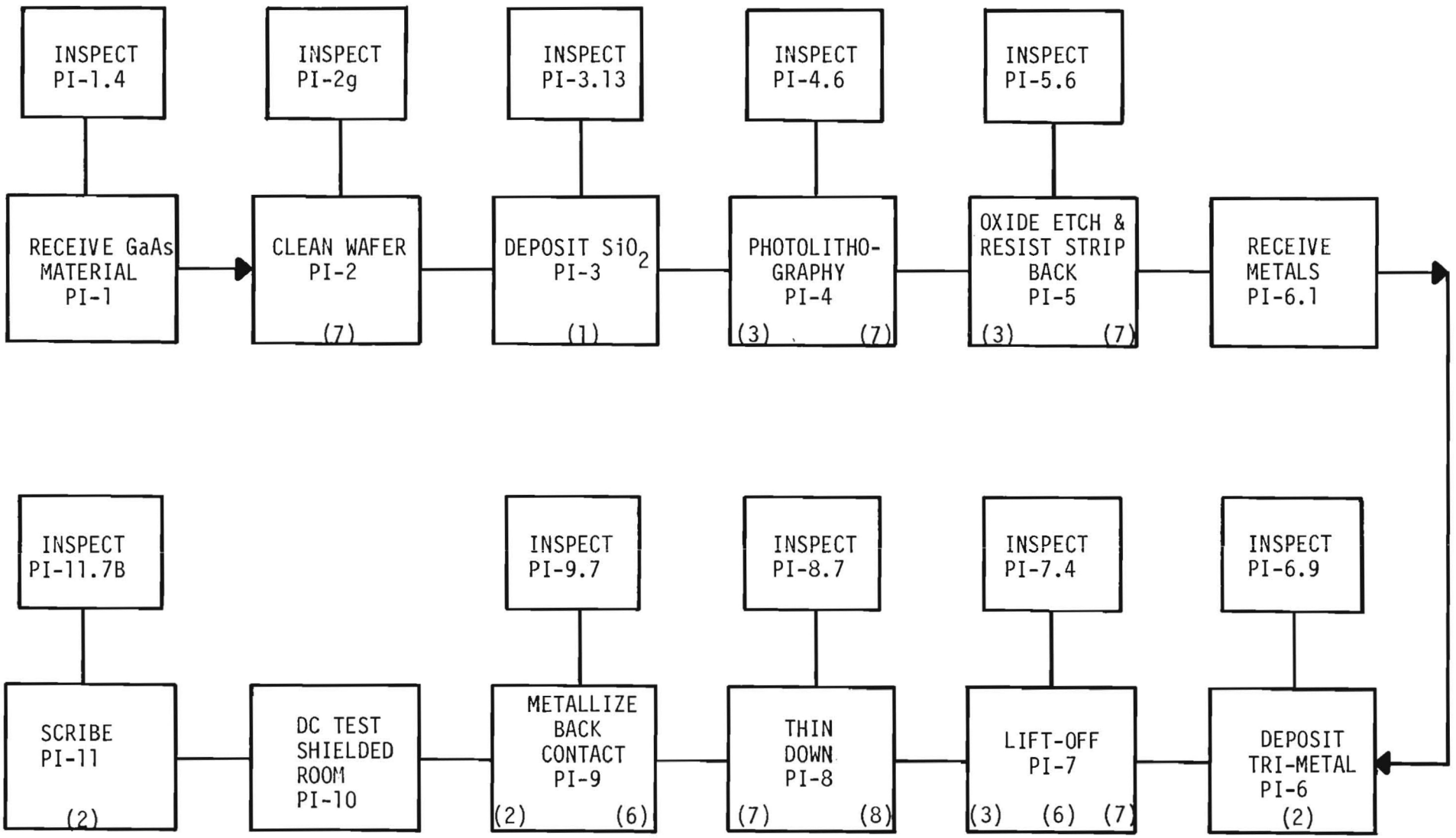
MILLIMETER WAVE MIXER

DIODES HUGHES DRAWING

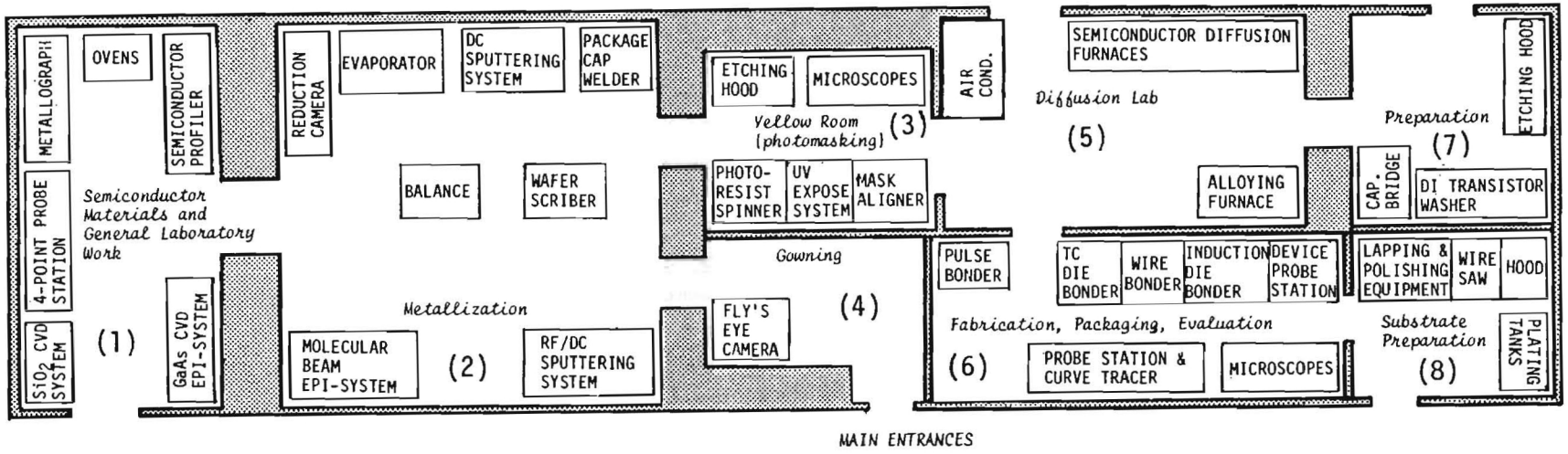
3414270 REV C

Prepared by
G. N. Hill
G N Hill 6-5-81

PROCESS FLOW CHART FOR MILLIMETER WAVE MIXER DIODES
Major Activity
Block Diagram




( ) denotes lab area in which process step takes place.




Layout and Major Equipment Location in the Microelectronics/Semiconductor Laboratory.

SHIELDED ROOM
THERMAL SOAK
STATION
dc TEST

SCOPE

To specify epitaxial gallium arsenide wafer material

APPLICABLE DOCUMENTS

Contract No. S8-738203-LV3
Hughes Drawing 3414270 Rev (C)

REQUIREMENTS

1. Gallium arsenide substrate characteristics to be supplied or as required.

   a. Boule supplier, Boule number and wafer number
   b. Orientation, 2° off < 100 > toward < 110 >
   c. Dopant, $T_e$
   d. Carrier Concentration $\geq 2 \times 10^{18}$ $cm^{-3}$
   e. Resistivity, 1.2 ohm $cm^3$
   f. Area, as required, typically 6-7 $cm^2$
   g. Backside, lapped flat

2. Gallium arsenide buffer layer characteristics

   a. Dopant, silicon
   b. Carrier concentration $\pm 2 \times 10^{18}$ $cm^{-3}$
   c. Thickness > 3 μm

3. Gallium arsenide, active layer characteristics

   a. Dopant, silicon
   b. Carrier concentration, $1.1 \times 10^{17}$ $cm^{-3} \pm 0.11 \times 10^{17}$ $cm^{-3}$
   c. Thickness, 0.25 μm ± .05 μm

QUALITY ASSURANCE PROVISIONS

4. Equipment

   a. Microscope 7-50x.

5. Inspect surface morphology under 7-50 power magnification. Any defect noted in 5a, b, c, will be cause for rejection.

   a. Surface haze
   b. Hillocks
   c. Cracks

6. Data sheets

   a. Impurity profile
   b. Vendor quality assurance document

7. Handling

   a. Do not touch wafer with bare hands.
   b. Do not slide wafer, face down, on any surface.
   c. Receiving will not open package immediately surrounding wafer.

SCOPE

To describe gallium arsenide wafer clean-up prior to depositing $SiO_2$

APPLICABLE DOCUMENTS

Contract Number S8-738203-LV3
Hughes Drawing 3414270 Rev. (C)

REQUIREMENTS

1. Equipment

   a. Wet chemical fume hood
   b. Hot plate, Model HPA 1915B, Thermolyne
   c. Microscope, 7-30X, Bausch and Lomb
   d. Sonic cleaner, Model 75, Beuhler Ltd.
   e. Sundry supplies: Tweezers, Tri-grip telfon holder, beakers, filter paper, petri dishes, etc.

2. Chemicals and Gases - Electronic grade or equivalent high purity

   a. Dry nitrogen gas, 99.994%.
   b. Hydrochloric acid
   c. Deionized water, filtered, 10 megohm or better.
   d. Methanol
   e. Trichloroethylene

3. Procedure

   a. Carefully remove gallium arsenide wafer from storage container.
   b. Grip wafer with tri-grip teflon tweezer.
   c. Prepare and submerse wafer into a beaker of trichloroethylene. Sonic agitate beaker for 1 minute.
   d. Prepare a second beaker of trichloroethylene. Heat to boiling. Immerse wafer into vapor for 30 seconds.
   e. Rinse wafer in methanol, then rinse in running DI water for 30 seconds.
   f. In a beaker, prepare 50 ml of hydrochloric acid. Also prepare 200 ml of deionized water. Heat HCl until bubbles form, then immerse the wafer into the HCl for 30 seconds. Rinse in the deionized water beaker for 30 seconds. Follow with 2 minutes of running deionized water rinse.
   g. Blow dry using $N_2$ opposed jet dryer.
   h. Inspect the wafer surface using the 7-30X microscope. Observe the reflected light from the wafer at various angles. Water spots or other visable contaminates is cause for rejection. Reclean if required.

i. Place wafer into clean, covered petri dish.
j. Label dish cover to retain wafer identity.

## SCOPE

To describe the procedure for growing an oxide layer.

## APPLICABLE DOCUMENTS

Contract No. S8-738203
Hughes Drawing No. 3414270 Rev (C)

## SYSTEM DESCRIPTION

The system schematic is shown in Figure 1. As the system is set up, the valves are contained in one of three groups. The control manifold houses the silane ($SiH_4$), nitrogen ($N_2$) and oxygen ($O_2$) control valves as well as acting as a mechanical support for the deposition chamber. The flowmeter panel contains the silane, nitrogen and oxygen flowmeters and flow valves; and the nitrogen and oxygen supply valves. The silane tank assembly includes the silane supply valve, the silane regulator outlet valve, the regulator purge valve, and the silane line purge valve.

## REQUIREMENTS

1. Gases

   a. Ultra pure nitrogen 99.999%
   b. Ultra pure oxygen 99.999%
   c. Electronic Grade 3% silane in nitrogen
   d. Dry nitrogen gas 99.994%

2. Equipment

   a. Air conditioned limited access area
   b. Hood, to vent gases
   c. Growth chamber, Setup shown in Figure 1
   d. Calibrated color comparison tablet.
   e. Hot plate, HPA1915B, Thermolyne
   f. Sundry supplies; tweezers, petri dish, filter paper, etc.

3. Start-up

   a. Attach thermocouple bridge to check system operating temperature for 300 °C.
   b. Turn on mass flow meter 30 minutes prior to using system.

4. Set valves to their proper initial positions

   a. Silane control valve - closed - handle vertical
   b. Nitrogen control valve - off - handle vertical
   c. Oxygen control valve - closed - handle vertical
   d. Nitrogen supply valve - closed - clockwise
   e. Oxygen supply valve - closed - clockwise
   f. Silane flow valve - N/A
   g. Nitrogen flow valve - N/A
   h. Oxygen flow valve - N/A
   i. Silane supply valve - closed - clockwise
   j. Silane regulator outlet valve - closed - clockwise
   k. Silane line purge valve - off - handle vertical
   l. Regulator purge valve - off- clockwise

5. Purge system

   a. Open nitrogen and oxygen supply valves (CCW).
   b. Open nitrogen control valve (handle vertical).
   c. Set nitrogen flow valve for a flowmeter reading of 6 (black ball).
   d. Simultaneously set the silane control valve to "$SiH_4$" and open the silane line purge valve (horizontal).
   e. Set silane mass flow meter to read 200%.
   f. Set oxygen control valve to "$O_2$".
   g. Set oxygen flow to 6.5 (black ball).
   h. Allow system to purge for a total of five minutes.

6. Load wafer

   a. Set oxygen and silane control valves to "Vent".
   b. Lower jack while carefully guiding platform from the chamber.
   c. Using tweezers, carefully place the wafer face up on the platform. Avoid scraping the platform which may generate $SiO_2$ particulate matter. If such matter is generated it may be removed by blowing with nitrogen gas.
   d. Raise platform until the crossbar supporting the chamber begins to flex.
   e. Turn on table rotation switch.

7. Establish gas flow

   a. Turn silane line purge valve off (vertical).
   b. Turn silane supply valve on (CCW).
   c. Turn regulator outlet valve on (CCW).
   d. Reset silane flowmeter for a flow of 85%.
   e. Increase nitrogen flow to 12.
   f. Allow two minutes of nitrogen and silane flow.

8. Grow oxide, 5000 $\pm$ 500 Å Thickness required.

   a. Turn silane control valve to "$SiH_4$".
   b. Quickly turn oxygen control valve to "$O_2$"
   c. Watch oxide growth carefully. Maintain silane flow at 85% as required. During the $SiO_2$ deposition, observe and compare the

wafer surface color under cool white fluorescent light with the calibrated color comparison chart. The deposition rate is approximately 500 Å per minute, therefore; approximately 10 minutes is required to deposit 5000 Å.

d. Turn silane and oxygen control valves to "Vent" when 5000 Å is grown.

9. Turn silane tank assembly off

a. Close silane supply valve (CW).
b. Open silane flow valve for rapid flow, 200%.
c. Watch the high scale regulator carefully. When it begins to approach zero, start closing regulator outlet valve.
d. When the low scale regulator begins to drop, quickly finish closing the regulator outlet valve (CW).

10. Purge system

a. Open silane line purge valve (horizontal).
b. Reduce nitrogen flow to between 5 and 6.
c. Turn oxygen control valve to "Closed".
d. Close oxygen supply valve (CW).
e. Close nitrogen control valve (vertical)
f. Wait two minutes.
g. Turn silane control valve to "Closed".
h. Close silane line purge valve (vertical).
i. Close nitrogen supply valve (CW).

11. Retrieve wafer using tweezer. Utilize caution noted in PI-3, 6c.
a. Turn off table rotation switch.
b. Lower jack.
c. Remove wafer and return it to the clean, covered container.
d. Raise jack.

13. Inspect

a. Proper color, 5,000 ± 500 Å. Determined from the calibrated color comparison tablet.
b. Uniform color across wafer surface.
c. Note: If the deposited film is rejected, the oxide may be etched away and a repeat deposit cycle initiated. Consult this process instruction PI-3, 14.

14. Reclaim wafer. Note: Proceed only if the wafer is rejected.

a. Prepare separately 50 ml of hydrofluoic and hydrochloric acid. Use a plastic beaker for HF. Prepare separate 200 ml beakers of deionized water.

Grasp the wafer in the trigrip teflon tweezer. Immerse the wafer into the HF for 1 minute, then rinse in the di water. Follow with 1 minute of running di water rinse.

c. Heat the hydrochloric acid until bubbles form.
d. Immerse the wafer into the hydrochloric acid for 30 seconds. Rinse in the di water for 30 seconds. Follow with 2 minutes of running deionized water rinse.
e. Blow dry using the $N_2$ opposed jet drier. Place the wafer into the covered container and repeat, PI-3.

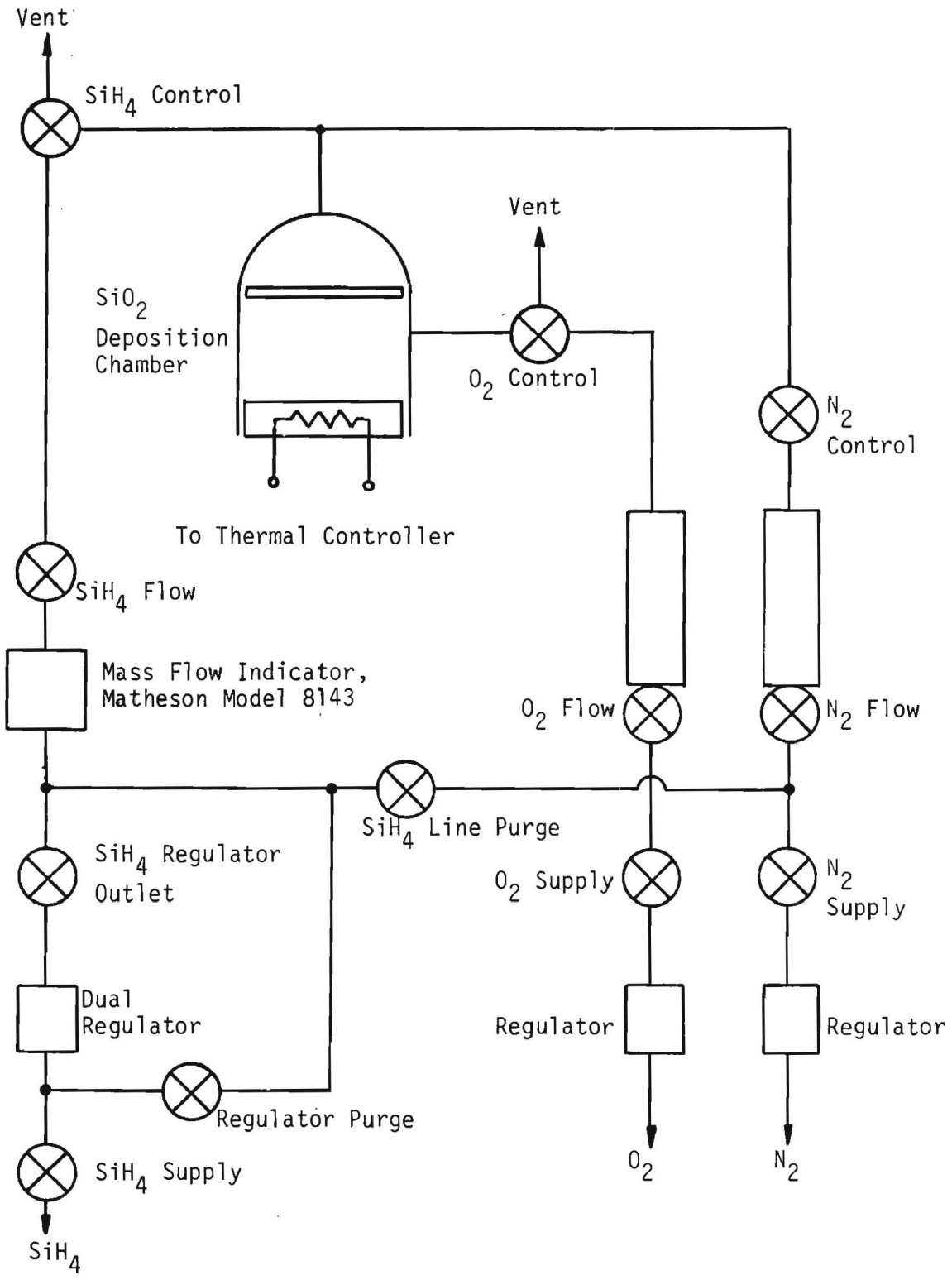



Figure 1. Oxide Growth System Schematic.

SCOPE

To describe the procedure for delineating the diode geometry

APPLICABLE DOCUMENTS

Contract No. S8-738203-LV3
Hughes Drawing 3414270 Rev (C)

REQUIREMENTS

1. Equipment - set up in air conditioned, limited access room.

   a. Wet chemical fume hood
   b. CVD $SiO_2$ deposition system. Lab built.
   c. Photoresist spinner, model no. AHT2A-T, Headway Research, Inc.
   d. Ovens, 95 °C and 110 °C.
   e. Mask exposure system. model no. 686B, Kulicke & Soffa.
   f. Traveling stage microscope, 100x to 800x power, Unitron, model no. TMS-6560.
   g. Sonic cleaner, model no. 75, Buehler, Ltd.
   h. Hot plate, model no. HP-A1915B, Thermolyne.
   i. Sundry supplies: tweezers, beakers, petri dishes, etc.
   j. Mask A2960, or as determined by process Engineer.

2. Chemicals and gases, electronic grade or equivalent high purity.

   a. Trichlorethylene
   b. Methanol
   c. DI water 10 megohm or better.
   d. Hexamethyldisilazene (HMDS)
   e. AZ 1350 J - photoresist thinned 3:1
   f. AZ 351 developer
   g. AZ thinner

3. Apply Photoresist - Preset speed, 6000 RPM, time: 25 secs.

   a. Remove wafer from transport container. Note: Use tweezer when handling wafer.
   b. Place wafer onto spin chuck. Turn on vacuum.
   c. Apply HMDS. Cover entire surface. Let soak for 30 secs.
   d. Press start spin, let stand for 30 secs before applying resist.
   e. Apply thinned AZ1350J resist dropwise to the wafer center until one half of the wafer is covered, start spin immediately.
   f. Release vacuum and remove wafer, placing wafer into a clean covered petri dish.
   g. Place dish into 95 $\pm$ 5 °C oven. Remove cover, then bake for 25 minutes.

4. Expose wafer - Turn on mask aligner, preset exposure time for 5 secs. Allow unit to warm up for at least 15 minutes. Load mixer mask no. A 2960. Keep mask in storage container when not in use. DO NOT TOUCH SURFACES.

   a. Following bake, allow wafer to cool in covered dish for 5 minutes.
   b. Center a new millipore filter HAWP 25 on aligner chuck. Place wafer, centered, on filter.
   c. Ensure that mask vacuum is off. Rotate wafer chuck into position under mask. Lower ball chuck to lowest position, manual adjust.
   d. Press pantograph button. (Raises ball chuck partially). Turn on mask vacuum, then continue raising ball chuck until the wafer just contacts the mask.
   e. Increase separation by one click of separate switch.
   f. Press pantograph button again (clamps wafer to mask).
   g. Press exposure.
   h. When cycle is complete, rotate chuck away from mask. Remove wafer.

5. Develop - Mix developer 1 part AZ351 to 3.5 parts DI $H_2O$ (20 ml;70 ml). Also prepare DI $H_2O$ rinse in a 250 ml beaker.

   a. Place wafer onto vacuum hold-down wand.
   b. Immerse into developer for 45 seconds, rinse immediately.
   c. Rinse again in running DI $H_2O$ for 2 minutes.
   d. Blow dry using dry nitrogen gas.

6. Inspect

   a. Inspect the images formed by the process by first using low power (100x) to scan the wafer for gross defects; such as cracks or resist lifting, then use 800x to examine the edge acuity of the cross geometries. The diode holes should be clear of resist, however, due to the interference fringes present, it may be difficult to observe. A small corner of the wafer may be broken away and subjected to SEM analysis if necessary.

7. Post bake

   a. Bake for 10 minutes at 110 °C.
   b. Remove from oven and store in clean, covered glass petri dish.

SCOPE

Describes the delineation of the deposited oxide, vacuum bake and resist strip back, preparatory to metal deposition.

APPLICABLE DOCUMENTS

Contract No. S8738203-LV3
Hughes Drawing 3414270 Rev ( C )

REQUIREMENTS

1. Equipment - setup in an air conditioned, limited access facility.

   a. Wet chemical fume hood
   b. RF sputtering system - to be used for high vacuum bakeout of the photoresist. Perkin Elmer model 2400, with substrate heat and temperature monitoring provisions.
   c. Plasma strip system - LFE Corp, model PDS/PDE 301.
   d. Traveling stage microscope - Unitron model TMS 6560, 100 to 800x.
   e. General purpose microscope - 7-30x, Bausch & Lomb
   f. Sundry supplies: plastic beakers, teflon trigrip tweezers, filter paper, graduated cylinder, safety goggles, plastic gloves, teflon stir rod.
   g. Timer - seconds, minutes.

2. Chemicals and gases - electronic grade or equivalent, high purity.

   a. Hydrofluoric Acid
   b. Ammonium Fluoride
   c. Oxygen gas 99.994%
   d. Deionized water, 10 megohm or better
   e. Nitrogen gas 99.994%
   f. Microclean - used as wetting agent.

3. Procedure - define diode area in deposited oxide.

   Secure wafer processed in PI-4. CAUTION: wear protective goggles and gloves. HF extremely hazardous in contact with skin, eyes and lungs.

   a. In a fume hood, dispense 60 ml ammonium fluoride into 100 ml plastic beaker, then add 10 ml of HF. Stir with teflon rod. Let solution stand for 1 hour.
   b. Prepare 200 ml DI rinse in plastic beaker.
   c. Prepare wetting agent. 1 drop microclean in 200 ml DI water.

d. Grip wafer with teflon tri-grip tweezer.
e. Immerse wafer into wetting agent then immediately immerse wafer in $NH_3$ HF etch solution. Start timer. Etch for 45 seconds. Stop timer and rinse wafer in DI water beaker, then running DI water.
f. Inspect etch progress by observing color change in orientation crosses. Color should be blue (1200 Å). The etch rate is approximately 85 Å per second.
g. Continue etching for 10 more seconds. Observe again, cross will appear slightly tan to clear. Etch again for 5 more seconds.
h. Rinse thoroughly in running DI water.
i. Blow dry using $N_2$ gas, then return wafer to petri dish storage container.

4. Procedure - high vacuum resist bakeout.

Obtain wafer from oxide etch step PI-5, 3i. Transport to sputtering system for vacuum bakeout.

a. Push start vent switches to open vacuum chamber.
b. Raise chamber head carefully so as not to stretch wires. Place wafer onto heated stage, face up.
c. Lower chamber head. Push start pump. System will automatically sequence. Turn on vacuum gauge.
d. Charge system with $LN_2$.
e. When system pressure reaches $7 \times 10^{-7}$ Torr, turn on heater supply and temperature monitor.
f. Increase temperature to 150 °C. Let stabilize and bake for 30 minutes.
g. Lower temperature. Allow to cool to 30 °C.
h. Push start vent to open chamber.
i. When vented, remove wafer. Close chamber and start pump. Turn off vacuum gauge.
j. Place wafer into covered petri dish.

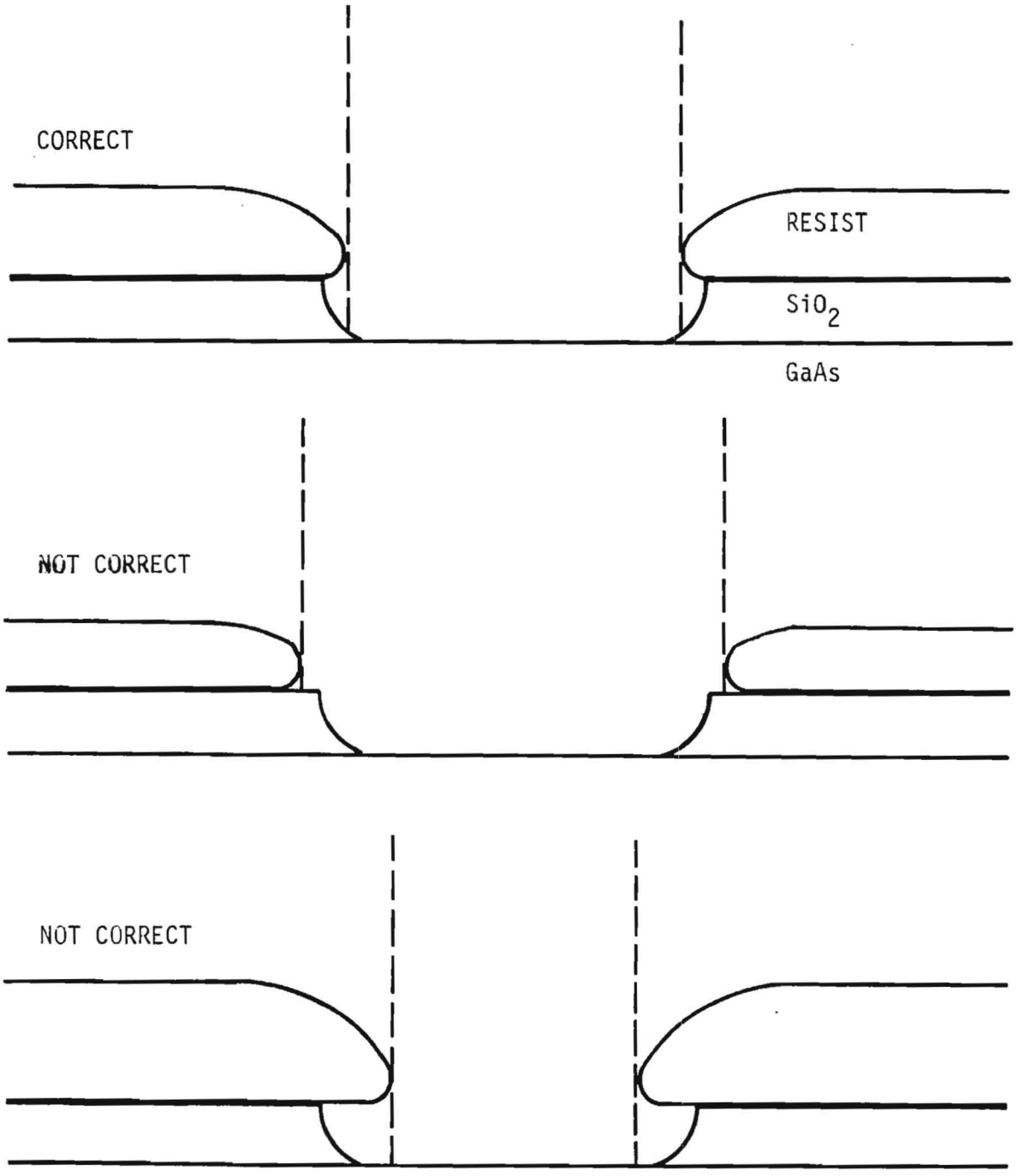
5. Procedure - resist etch back.

Obtain wafer from high vacuum bakeout step PI-5, 4j. Transport to plasma strip reactor.

a. Turn on vacuum pump. Turn on main system. Set mode to strip. Press start cycle. Preset RF power to 350 watts. Set $O_2$ flow to 30 cc/min. Set timer to 4.75 minutes.
b. Start sequence. Push vacuum release; open chamber. Place wafer on carrier face up. Close chamber. Press start cycle. System will auto sequence.
c. Open chamber. Remove wafer. Place into covered petri dish.

6. Inspect

Under microscopic examination, determine that the photoresist has been removed sufficiently in the etched oxide openings. Figure 1 shows the desired etch back.




PI-5

Figure 1. Plasma Strip. Photoresist Strip Back.

SCOPE

To describe procedure for depositing anode contact metals by E-beam evaporation methods.

APPLICABLE DOCUMENTS

Contract No. S8-738203-LV3
Hughes Drawing 3414270 Rev. (C)

REQUIREMENTS

1. The contact metals Ti, Pt and Au described in the Process Instruction Section PI-6.1 will be deposited sequentially onto a surface delineated wafer processed in PI-4 and PI-5.

2. Equipment - setup in an air conditioned limited access facility.

   a. Wet chemical fume hood.
   b. E-beam evaporator system consisting of models VeB-6 E-gun, VeB-6c control, VeB-6T transformer, and lab modified vacuum system comprised of dual Ultex ion pumps, powered by a model 60-656 supply. System roughing is accomplished by a Welch, turbo-molecular pump model 3102. Included are three crucibles, precharged with metal described in PI-6.1.
   c. Tencor, Alpha Step Profiler
   d. Sundry supplies: tri-grip tweezers, beakers, microscope slide.timer, filter paper, apiezon black wax,petri dishes, safety goggles, plastic gloves, glass dish 8 x 10 x 2", etch rate graph and glass thermometer.

3. Chemicals and gases - electronic grade or equivalent high purity.

   a. Hydrochloric acid
   b. Phosphoric acid
   c. Hydrogen peroxide
   d. Dry nitrogen gas 99.994%
   e. Deionized water - 10 megohm or better.
   f. Hydrofluoric acid
   g. Techni-strip AU.
   h. Trichloroethylene

4. Safety

   a. Dispense chemicals in a safe manner. Do not allow contact with skin. Wear protective goggles and gloves.

5. Procedure - surface preparation.

   Obtain wafer completed and described in PI-5.

NOTE: Do not prepare wafer unless it can be loaded into the vacuum chamber immediately following surface preparation.

a. Prepare surface etch solution consisting of 1 part hydrogen peroxide, 3 parts phosphoric acid, and 50 parts room temperature DI water. Also prepare a beaker of DI rinse water.
b. Dispense chemicals using Repipet dispensers of the type 13-678v Fisher Scientific Co., 90 ml of etch solution is used. After mixing, the beaker is placed in a flat glass dish, half filled with room temperature water.
c. Let etch stand for 5 minutes. Measure the temperature of the etch solution. Consult the etch rate graph shown in Figure 1 and determine the time necessary to remove approximately 0.05 μm of GaAs in the oxide opening.
d. Grasp the wafer, face up, with the trigrip tweezers. Immerse wafer in the etch solution. Start timer simultaneously and etch for the required time.
e. Rinse immediately in the DI water beaker, then rinse in running DI water for 3 minutes.
f. Blow dry using filtered $N_2$ gas. Place wafer into clean, covered petri dish.

6. Procedure - load wafer into vacuum evaporator

The vacuum evaporator is described in Figure 2. The system idles in a pumped-down condition having a pressure of 2-5 x $10^{-9}$ Torr. The interlock gate valve is closed. The turbo isolation valve is closed and turbo pump is off. The mechanical pump is running with the foreline valve closed.

a. Ensure that the sample slide rod is pulled into interlock chamber and the interlock gate valve is closed.
b. Vent the interlock chamber. Open all $N_2$ valves.
c. Loosen all of the bolts holding the sample rod flange. $N_2$ will constantly purge the interlock chamber. Remove all but the top bolt. Have an assistant remove this bolt while you hold the sample rod flange and support tube.
d. Pull the sample rod flange away from the system. Place flange into the bench vise provided for that purpose.
e. Load resistance monitor. Slip into the clips provided. Check for short circuits.
f. Load wafer, face up, placing it into the wafer clip provided.
g. Install a new copper gasket into the flange.
h. Replace sample rod flange. Ensure that the wafer faces down when installed.
I. Close $N_2$ purge valves.

7. Pump Down Interlock Chamber; then Main Chamber.

a. Slowly open foreline valve. Watch vacuum gauge on front panel. When the pressure indicates 100 microns or less, turn on turbo pump.

b. When the pressure indicates zero on the pressure gauge, begin cracking open the turbo isolation valve. A gurgling in the mechanical pump and an increase in pressure reading to between 5 and 10 Torr indicates proper pumping. Do not crack valve further until pressure decreases to 0.5 Torr. When pressure indicates zero, open valve about 2 inches further. Allow to pump in this condition for 45-60 minutes.
c. Close the isolation valve.
d. Open the interlock gate valve while observing the ion supply pressure indicator. Pressure will rise to the mid $10^{-6}$ Torr scale.
e. Turn on the titanium sublimation pump. Pressure will rise, then drop to less than $10^{-6}$ Torr. Continue observing the ion gauge. A slight increase in pressure will again be observed. Turn off titanium pump. Pressure should again drop. When drop ceases, again turn on titanium pump. Watch rise, drop, and slow rise again.

   Note that with each cycle of turning titanium on and off, the base pressure will be lower. Continue this procedure until system remains stable - well on the $10^{-7}$ Torr scale.

   The best results have been obtained when the system is allowed to pump at least 16 hours, attaining a base pressure of 2-5 x $10^{-9}$ Torr.

f. Connect ohmeter to the resistance monitor terminal.

8. Evaporation of the Tri-metal System - Ti, Pt, and Au.

   a. Preheat all of the metal charges by sequentially beaming them for 20 seconds to their evaporating temperature. Titanium - 0.7 kW, 11 kV range; Platinum - 1.5 kW, 15 kV range; Gold - 0.6 kW, 11 kV range.
   b. Position the titanium crucible in the beam; then again turn up the E-gun beam current to 0.7 kW for 10 seconds.
   c. Lower the beam current to idle the titanium at 0.125 kW. This temperature will supply enough radiant heat to increase the wafer temperature to approximately 150 °C which provides a final bakeout.
   d. Insert the wafer sample rod into the main chamber. Open the shutter and allow the wafer to heat for 75 seconds. Increase the beam current to 0.7 kW. Monitor the change in resistance on the ohmeter. When 250 ohms is attained (20 seconds), close the shutter and slide the sample rod out of the main chamber. Lower the beam current to idle, 0.125 kW. Allow the sample to cool. Watch the resistance monitor. When stable, again insert the wafer and repeat two more 20 second intervals, allowing to cool each time. When the monitor reads 60 ohms, reduce the time for the next insertion to 15 seconds; then 5 seconds until approximately 45 ohms is attained. Pull sample rod back into the interlock. Turn off the beam power.
   e. Position the platinum crucible in the E-beam. Turn the voltage range switch to 15 kV. Turn up the beam power to 1.5 kW. After 30 seconds, insert wafer into main chamber. Open shutter for 2 seconds; then pull sample rod back and allow to cool. The film monitor

resistance should now read 35 ohms. Slightly lower is acceptable (30 ohms). If higher, repeat for 2 seconds more. Turn off the beam power.

f. Position the gold crucible in the E-beam. Turn the voltage range switch back to 11 kV. Turn up the beam power to 0.6 kW. Insert the sample rod and open the shutter for 5 seconds; then retract the sample rod. Allow to cool and repeat 3 cycles. The film monitor should read 1.6 $\pm$ .3 ohms when completed. Turn off E-beam supply. Retract sample rod sufficiently to close gate valve.

g. Close the interlock gate valve. Open $N_2$ purge valves. Disconnect ohm meter. Loosen bolts to remove sample rod flange as performed in 6.c.

h. Remove wafer and resistance monitor. Reload new monitor, if desired. Place wafer into covered petri dish. Label run number, e.g. GTRAY 9A16-(No.)

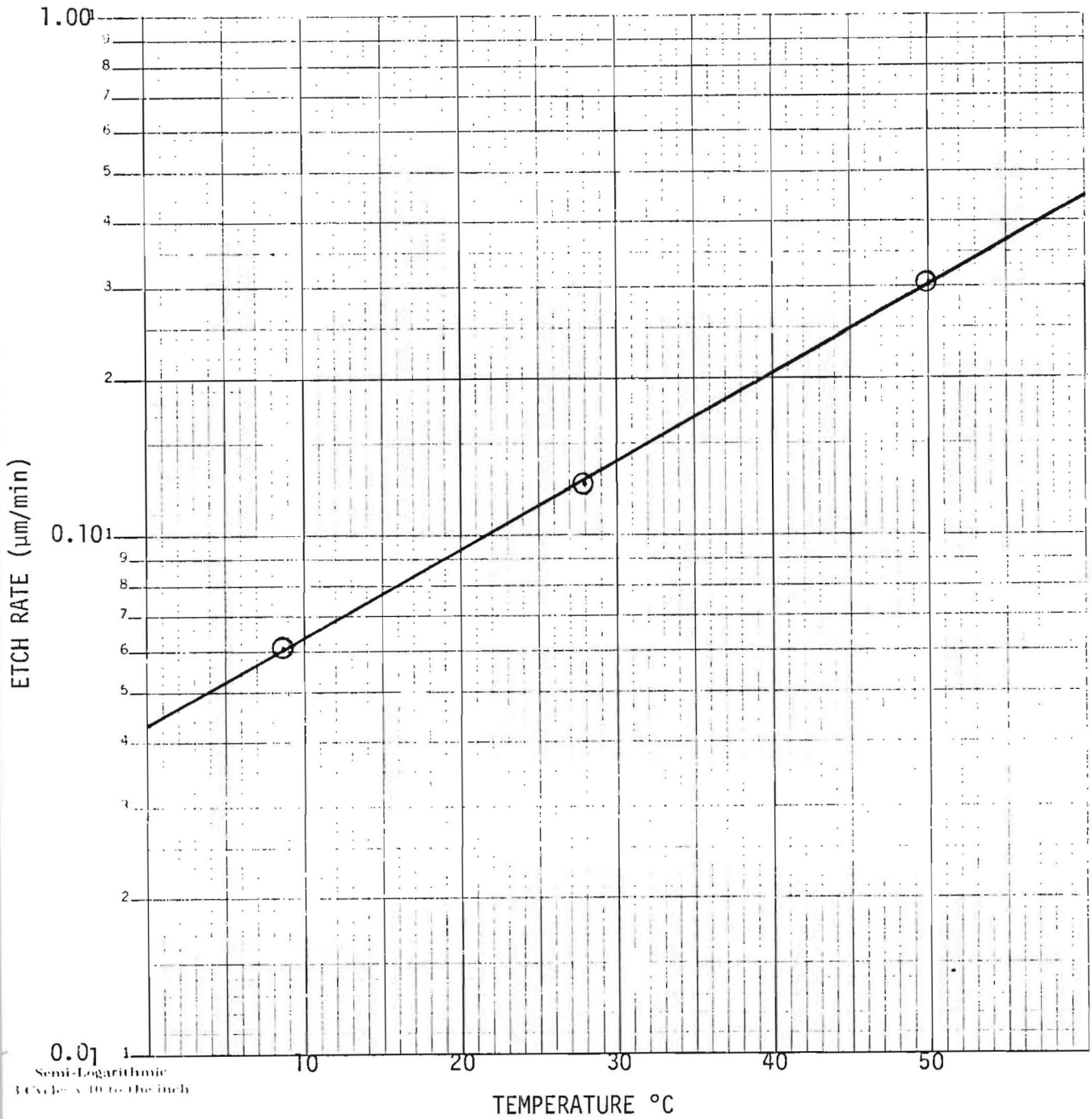
9. QUALITY ASSURANCE

The resistance monitor for each run will be preserved. One end of the monitor may be cleaved and subjected to selective etching of the cleaned interface. A second method may employ a completed masked and etched cross on the GaAs diode chip.

a. Cleave sample and mount to SEM stub, cleaved edge up.
b. Etch sample in 60 °C Techni-strip Au for 10 seconds. Delineates gold film. Then rinse in di water for 30 seconds.
c. Etch in 10% HF for 10 seconds. Delineates titanium film. Then rinse in di water for 30 seconds.
d. Platinum film remains unaffected.
e. SEM photomicrographs will serve as file data.

OR

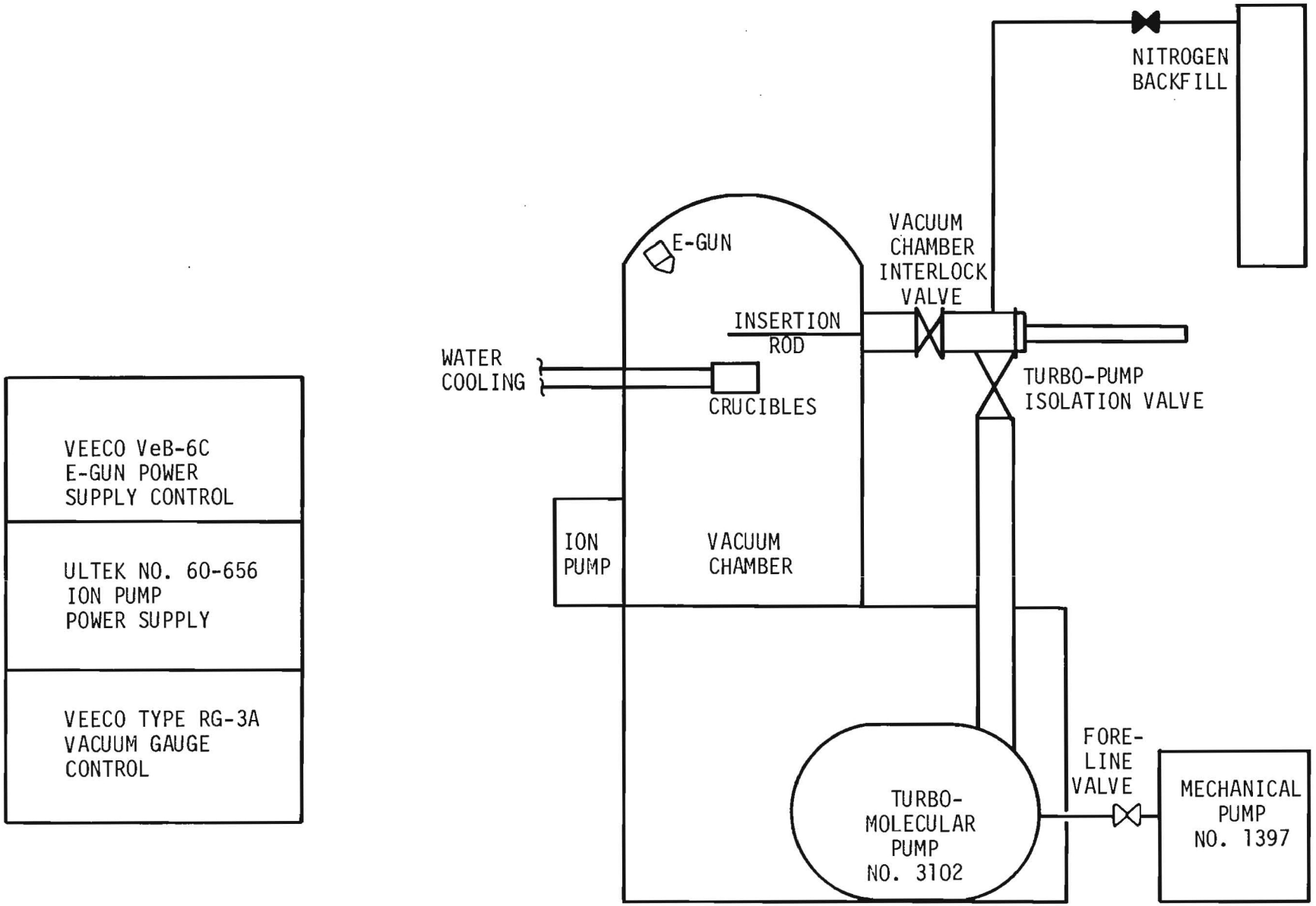
a. Mount a chip in black wax onto a glass slide.
b. Mask off a portion of the cross geometry using black wax.
c. Etch in 60°C Techni-strip to remove the exposed gold film. Then rinse in Di water. This creates the gold platinum step.
d. Etch in 10% HF for 1 minute. This etches the titanium under the platinum, creating a platinum titanium step. Then rinse in Di water and $N_2$ blow dry.
e. Remove wax mask using trichloroethylene.
f. Step profile the resultant etch steps on the Alpha Step Profiler.
g. Attach the profile data to the run sheet.




PI-6

Figure 1. Etch Rate Graph.

Figure 2. E-beam system block diagram.



SCOPE

Describes contact metals for anode and cathode contacts

APPLICABLE DOCUMENTS

Contract number S8-738203-LV3
Hughes Drawing 3414270 Rev (C)

REQUIREMENTS

Anode contact

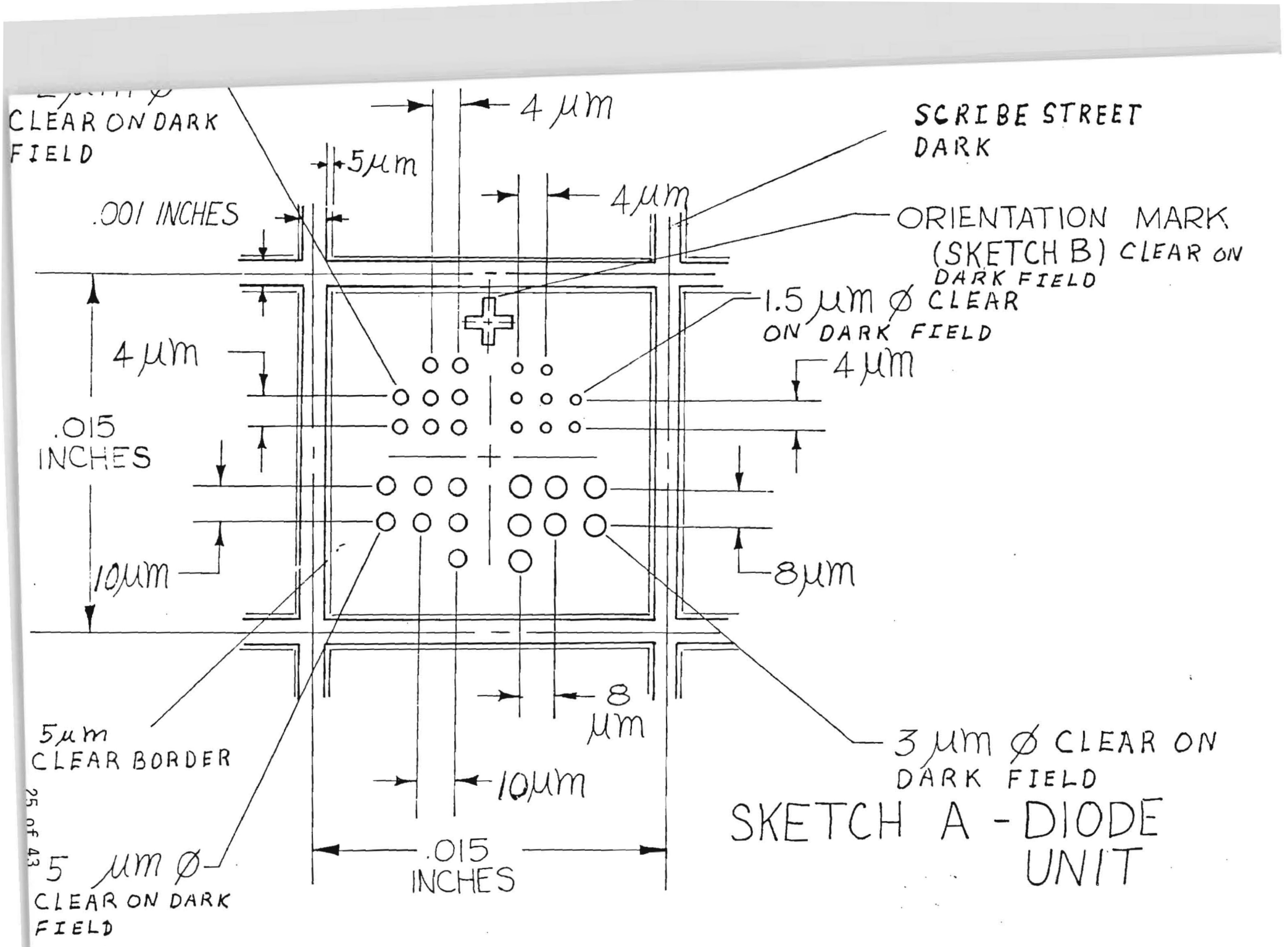
1. Diodes will be produced utilizing a tri-metal system for the anode contact composed of titanium, platinum and gold.
2. The deposited pattern will be in accordance with sketch figures A, B and C.
3. Titanium, 1000-1500 Å thick will be used to form the metal semiconductor contact
4. Platinum, 500 Å thick, will be used as an intermediate metal to prevent the formation of a resistive titanium gold compound.
5. Gold 2000 Å thick will be used as the external contact metal.

Cathode Contact

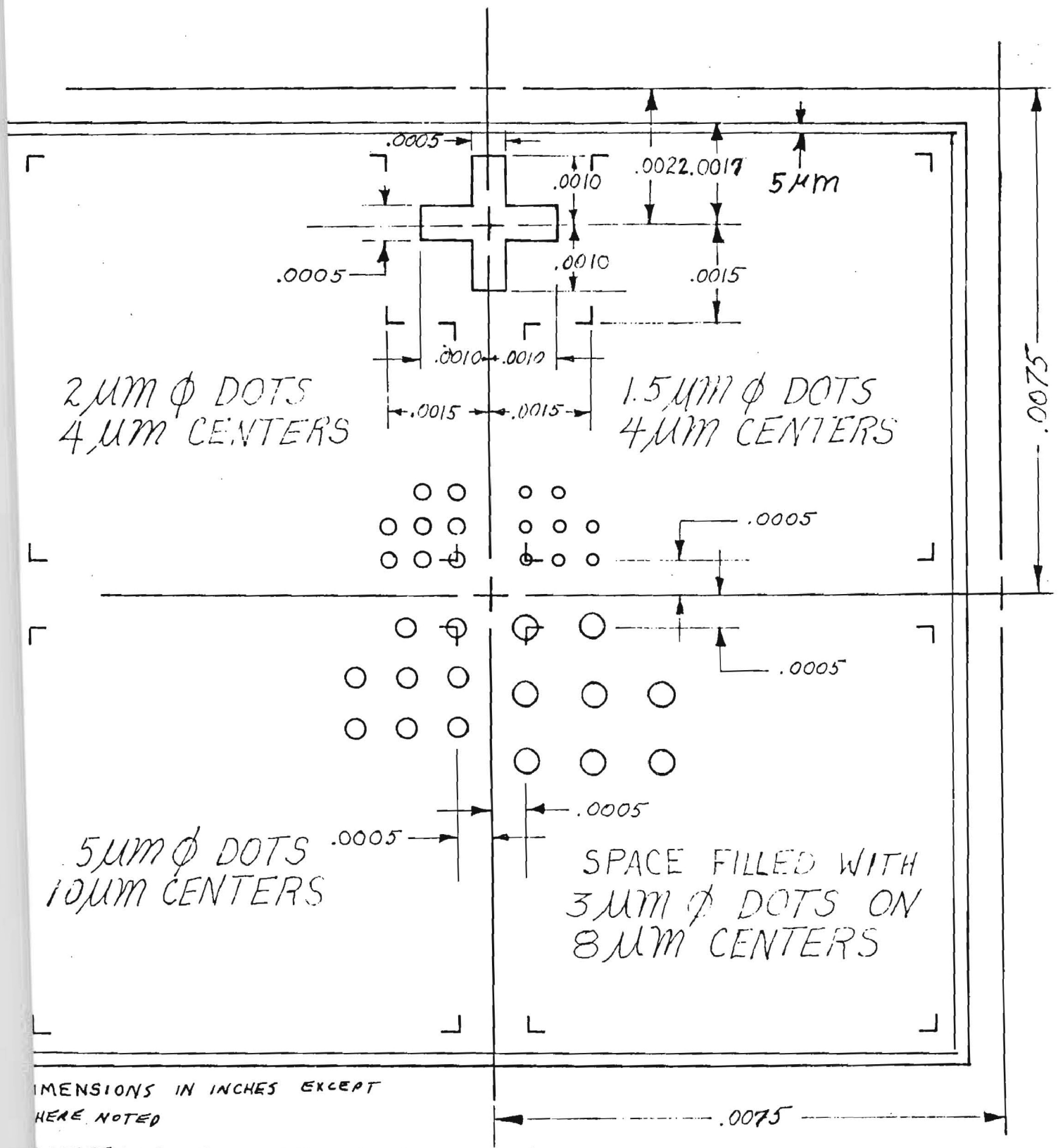
6. Gold-germanium alloy, consisting of 88% gold and 12% germanium will be used as the back contact metal. A nickel layer will follow which will serve to stabilize the alloy during heat treatment.
7. The alloy will be further coated with a similar tri-metal described in 3, 4 and 5 after heat treating the deposited alloy.

Quality Assurance

8. All metals to be at least as good as, or better than, 99.97% pure.
9. Before depositing metals, they will be heated to their evaporation temperature until such time as the observed charge in each crucible is fully melted and remains stable under the condition; when the beam power is increased 20% for 10 seconds in excess of the established running conditions described in PI-6, 8a.
10. Deposition process documented by process instruction PI-6.




SKETCH A - DIODE UNIT

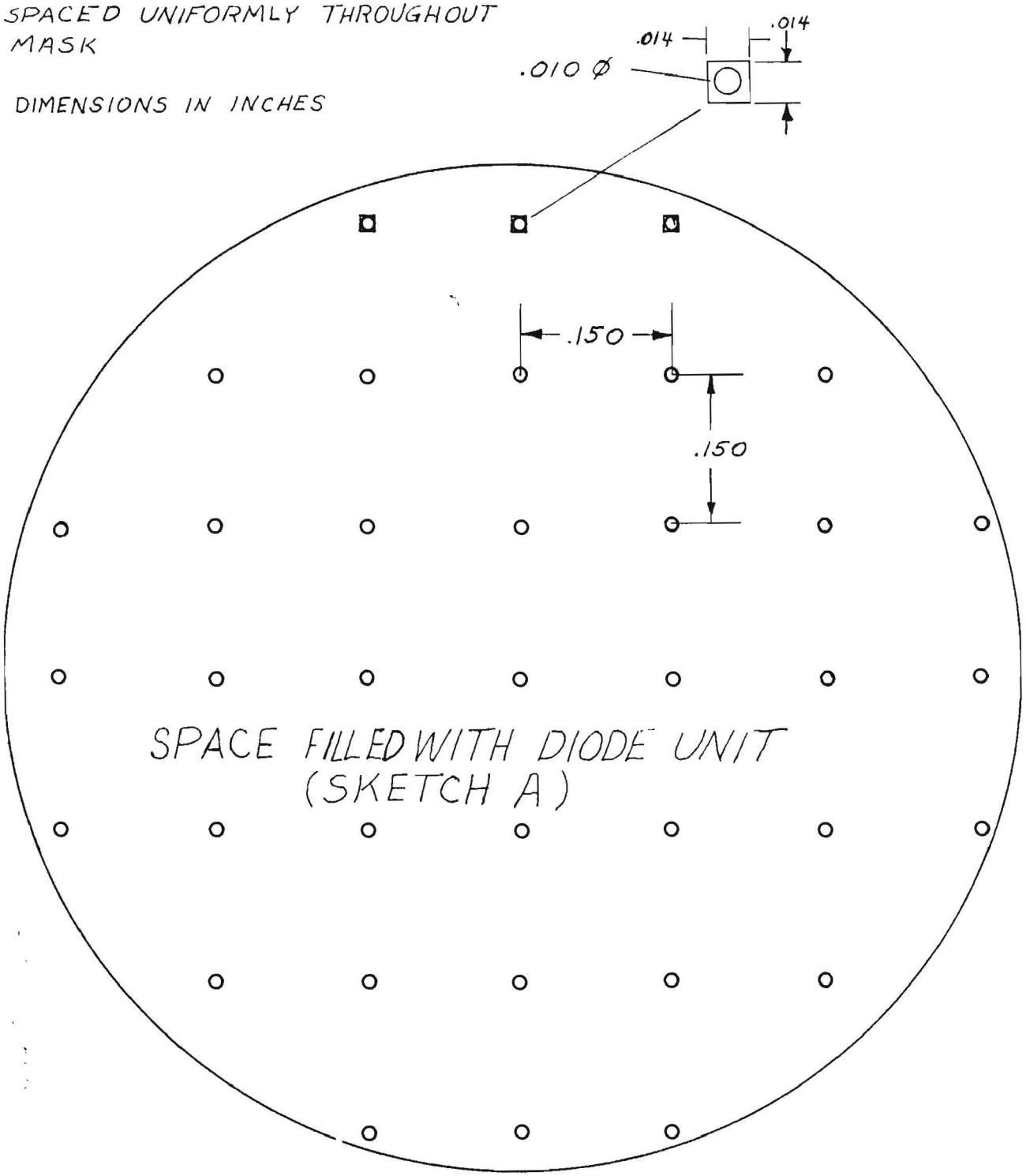



IMENSIONS IN INCHES EXCEPT
HERE NOTED

KETCH B - ORIENTATION & DOT ALIGNMENT MARKS

1% PROFILE TEST DOTS
SPACED UNIFORMLY THROUGHOUT
MASK

DIMENSIONS IN INCHES




SKETCH C - PROFILE DOTS

SCOPE

To describe clearing the wafer surface of undesired metal and photoresist.

APPLICABLE DOCUMENTS

Contract No. S8-738203-LV3
Hughes Drawing 3414270 Rev. (C)

REQUIREMENTS

1. Equipment set up in an air conditioned, limited access facility.

   a. Wet chemical fume hood
   b. Hot plate HP 1915B
   c. Microscope 7-30x, Bausch & Lomb
   d. Microscope - 100-800x, Unitron model 6560

2. Chemicals - Electronic grade or equivalent, high purity.

   a. Trichloroethylene
   b. Apiezon hard wax, W.
   c. SEM stub
   d. Adhesive mylar tape, 3M
   e. Cotton swabs, 6" long
   f. 50 ml beakers.

3. Procedure

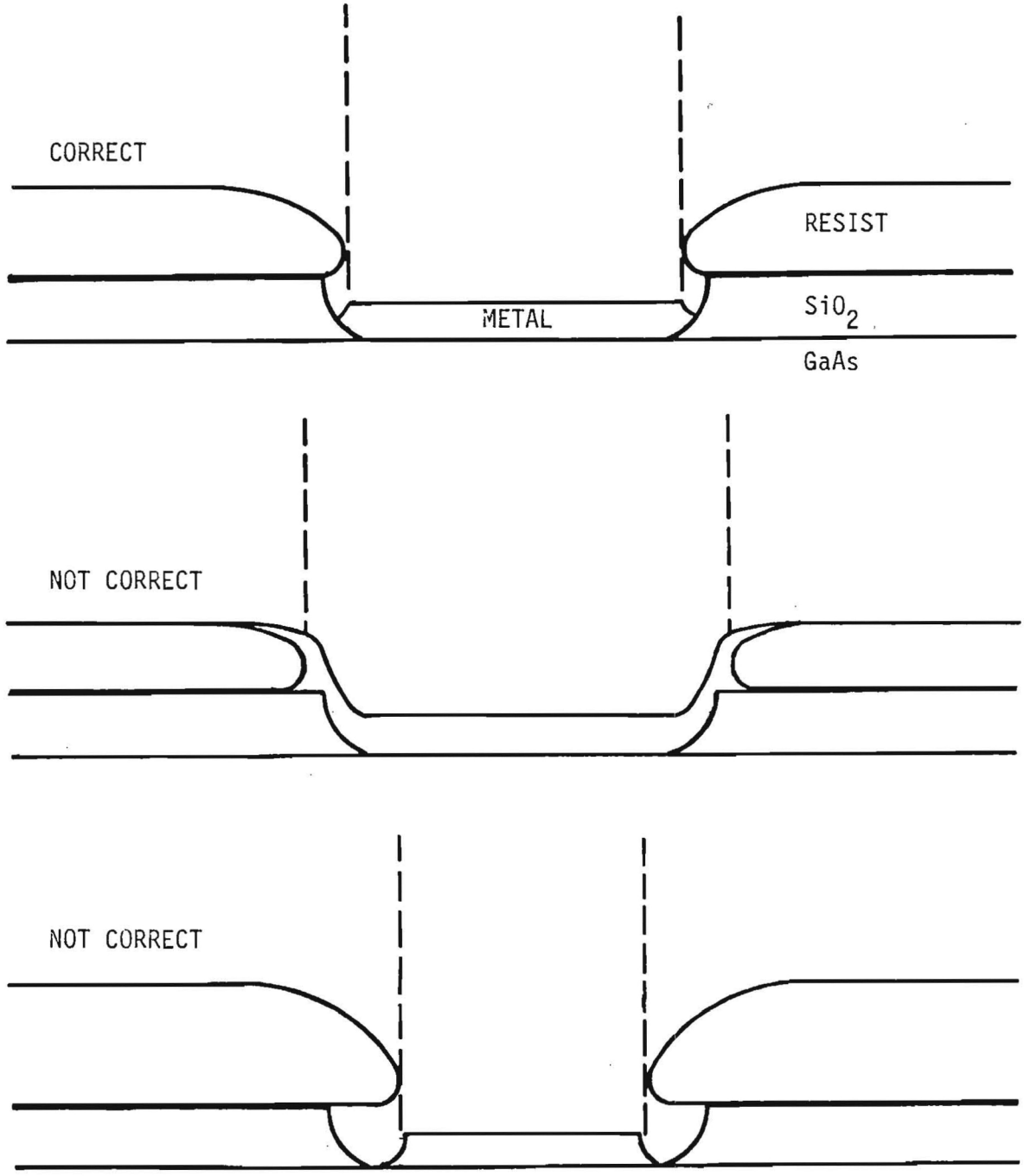
   Mount wafer, face up, onto a SEM sample stub.

   a. Heat stub so wax may be melted on the surface.
   b. Place wafer, face up, in wax. Gently apply pressure using swab stick to force out air. Let cool.
   c. Cut a small piece of mylar tape (approximately .2 inches wide x 1 inch long).
   d. Grasp each end of the tape between the thumb and forefinger. Adhesive will stick, each end to a finger. A smooth loop, protruding outward and in plane with the fingers, is the object.
   e. Under the low power microscope, gently and repeatedly contact and pull away the tape from the wafer surface. Some of the undesired metal and resist will pull away with each application and retraction of the tape. Lightly swabbing the surface with a trichloroethylene damped swab will improve the adhesion of the tape. Patience will be required, however, eventually all of the material will be lifted. Use a new piece of tape as required.

f. Remove the wafer from the stub after SEM analysis. Heat the stub to remelt the wax. Slide off, using a tweezer.
g. Hold the wafer in boiling trichloroethylene vapor to complete the wafer cleanup.
h. Place wafer into covered petri dish.

4. Quality Assurance

SEM analysis of the wafer shall be performed during liftoff and before step 3.g. The resist overhang may be examined to ensure that the deposited metal partially coats the sides of the oxide wall. Figure 1 shows the desired coverage.




PI-7

Figure 1. Metal Coverage.

SCOPE

Describes the process for thinning the wafer by mechanically lapping and polishing of the wafer backside.

APPLICABLE DOCUMENTS

Contract Number S8-738203-LV3
Hughes Drawing 341427C Rev. (C)

REQUIREMENTS

1. Equipment - setup in an air conditioned, limited access facility.

   a. Wet chemical fume hood
   b. Mazur lapping machine, model 601
   c. Buehler polishing machine, model 48-1553
   d. Lapping. polishing, holding fixture, lab built
   e. Gauge stand, reading in one-ten thousandths
   f. Hot plate, HPA1915B
   g. Pneumatic pressure stand, lab built
   h. Sonic cleaner, Buehler model 75
   i. Microscope General purpose 7-30x Bausch & Lomb

2. Chemicals and Gases and supplies. Electronic or best grade available.

   a. Parafin wax, Gulfwax
   b. Trichloroethelene
   c. Silicon carbide powder, 1000 grit, Buehler
   d. Clorox
   e. Deonized water
   f. Methanol
   g. Nitrogen gas 99.994%
   h. Sundry supplies, - Kimwipes, beakers, filter paper, tweezers, optical paper.

3. Procedure - obtain wafer from process step PI-7.

   a. Measure thickness of the wafer utilizing the gauge stand. Record the thickness nearest the wafer center.

4. Mount the wafer face down in parafin wax which is applied to the center post of the lapping fixture.

   a. Lay a sheet of filter paper on the hot plate set at 90 °C. Place the center post of the lapping fixture on the paper. When the side of the post nearest the hot plate is uncomfortably warm, remove it and apply a small speck of wax to the hot surface.

b. Lay the wafer face down in the wax then place a quarter size piece of lens tissue over the wafer.
c. Place the fixture centered under the pressure diaphragm of the pneumatic pressure stand. Lower the post and turn on air supply. This step flattens the wafer to the plane of the lapping fixture.
d. When cool, release the air pressure and remove the lapping fixture. Remove the lens tissue. Swab away excess wax using a cotton swab.
e. Place mounted wafer into the gauge stand. Adjust the dial to read the thickness recorded in step 3a.

5. Lap-grind the wafer to a thickness of 4 mils.

a. Prepare the lapping machine tray by sprinkling a 1/4 teaspoon amount of grit onto the glass flat. Add deionized water to form a slurry.
b. Insert the center post of the lapping fixture into the holder. Set the holder into the lapping tray. Move it around by hand to distribute the grit. Then set the speed control to 1/2 speed and turn on the machine. NOTE: Speed of material removal depends on area and distribution of grit. Time required to remove a fixed amount may vary, so check progress often until secure rate is established. Clean the wafer before measuring the thickness. Swab with deionized water. Blow dry using $N_2$ gas.

6. Polish the wafer to a thickness of $2^{+0.2}_{-0.0}$ mils

a. Sonic clean both center post and holder. Make sure no vestige of grit remains.
b. Prepare the Buehler polishing machine. Ensure that a clean satin polishing cloth is installed on the polishing wheel.
c. Mix 100 ml of clorox in 400 ml of deionized water. Pour it into a plastic squeeze bottle.
d. Soak polishing wheel with methanol then deionized water. Turn machine on slow speed and add clorox solution to wheel.
e. Place polishing fixture onto wheel. Slowly allow the center post to slide into position. Continue adding a small spray of clorox. Allow or cause fixture to turn in your hand as polishing progresses. NOTE: Measure polishing rate periodically. Polishing is purposely slow. 1 mil in 10 minutes is typical for an area of 1 $cm^2$. Rinse pad with deionized water before removing fixture. Then rinse and dry wafer before measuring thickness.
f. When the proper thickness of 2 mils is achieved, remove the wafer from the center post by immersing the post in boiling deionized water. Pour off the water, flood with methanol several times, and flood with trichloroethylene several times. Once again flood with methanol several times. Finish with a 3-minute running hot deionized water rinse. Keep the wafer on the side wall of the beaker during the pour off.
g. Carefully remove the wafer from the side of the rinse beaker. Lay it flat on a sheet of filter paper and carefully blow the wafer dry using Dry $N_2$. Place the wafer back into a clean covered petri dish.

7. Quality Assurance

The polished wafer should have a specular appearance, having no surface scratches or roughness.

a. Inspect, microscopically from various angles, utilizing the reflected light from the wafer surface. Magnification from 7-30x is acceptable.

SCOPE

Describes metallization of the cathode contact by vacuum evaporating a gold-germanium-nickel alloy for the contact metal. The alloy coated wafer is heat treated to reduce the contact resistance. Sputtered films of titanium, platinum and gold are then deposited, completing the contact.

APPLICABLE DOCUMENTS

Contract Number S8-738203-LV3
Hughes Drawing 3414270 Rev. (C)

REQUIREMENTS

1. Equipment - setup in an air conditioned, limited access facility.

   a. Wet chemical fume hood
   b. Vacuum evaporator, Veeco model 775
   c. RF sputtering system. Perkin Elmer model 2400
   d. Heat treat furnace, lab built
   e. Hot plate, HPA1915B
   f. Tencor Alpha Step Profiler
   g. Sundry supplies, tri-grip holder, beakers, filter paper, tweezers. Microscope slide & coverglass, apiezon blackwax. Thickness sample made from scrap GaAs.

2. Chemicals and gases, electronic grade or equivalent high purity.
   a. Hydrochloric acid
   b. Trichloroethylene
   c. Methanol
   d. Metals refer to PI-6.1
   e. Forming gas mixture, 90% $N_2$, 10% $H_2$ purities $\geq$ 99.99%.
   f. Argon gas, UHP 99.999%
   g. $LN_2$
   h. Hydrofluoric acid
   i. Techni-strip AU

3. Procedure - Obtain wafer from process step PI-8.

   a. Prepare vacuum evaporator. Fill cold trap with $LN_2$. Check pressure < $10^{-6}$ torr.
   b. Weigh out 40 mgs of AuGe alloy and 10 mgs of nickel wire then degrease all in boiling trichloroethylene vapor. Use filter paper cone to contain charges. Transport to vacuum evaporator.
   c. In a hood, pour 50 ml of HCl into a clean 100 ml beaker. Set up a rinse beaker with 200 ml of deionized water.

d. Remove wafer from petri dish; grasp with the tri-grip tweezer. Immerse wafer into HCl for 2 seconds, then rinse in distilled water beaker. Final rinse in running hot deionized water for 3 minutes. Be careful, wafer is fragile.
e. Dry using opposed jet $N_2$ blow station. Be very careful, wafer is fragile.
f. Place dried wafer into clean petri dish and transport to the vacuum evaporator.

4. Open vacuum chamber

a. Press stop cycle, system will vent and raise bell-jar automatically.
b. Remove substrate holder from chamber. Mount wafer under spring clips. Replace substrate holder.
c. Remove shield.
d. Place AuGe alloy charge into center tungsten boat. Place nickel charge in farthest boat. Shutter must be closed.
e. Replace shield.
f. Press start cycle. System will automatically lower bell-jar and pump down.
g. Evaporate charges. CAUTION! Use filter glass while observing melt. When system pressure achieves < $10^{-6}$ torr, turn up power in AuGe boat slowly while observing melt. When the tungsten dimple is wetted, open shutter and increase boat power until the charge is evaporated. Close shutter.
h. Switch boat power to the nickel boat. Increase power while observing melt. When melted, increase power further to 200 amps. while opening shutter. Leave power up for 30 seconds. CAUTION! Use filter glass while observing melt. Close shutter and allow to cool for 5 minutes.
i. Open system by pressing stop cycle. When system opens, remove substrate holder. Remove wafer from holder and place into clean covered petri dish.

5. Transport wafer to heat treat furnace.

a. Open forming gas valve and set flow to full scale. Slide furnace tray out of furnace and place the wafer on the tray. Return tray to preheat position.
b. Reduce forming gas flow to a reading of 5. Allow furnace to purge for 5 minutes.
c. Push tray into hot zone. Time for 3 minutes, then quickly slide furnace tray to the preheat position.
d. Remove tray after 15 seconds. Slide wafer onto clean filter paper in petri dish.
e. Turn off forming gas

6. Transport wafer to RF sputtering system.

a. Open system by pressing start vent.
b. Charge cold trap with $LN_2$ while venting.

c. Open chamber. Place wafer on clean BeO substrate with alloy side up. Also place thickness gauge near wafer.
d. Close chamber. Press start pump. System will automatically pump down.
e. When chamber pressure reads < $10^{-6}$ torr, press start gas and and open gas valve. Turn on RF generator. Turn vacuum gauge to position 1. Pressure should stabilize at 20 mtorr in 1 minute or less.
f. Presputter all 3 targets Au, PT, and Ti at 500 watts RF as follows: Au 2 minutes, Pt 2 minutes and Ti 10 minutes.
g. After 10 minutes of Ti presputter, rotate substrate wafer to coincide with the Ti target. Sputter for 1 minute then rotate table one revolution; sputter again for 1 minute and repeat this for 8 cycles. Film should be $\approx$ 1000 Å thick.
h. Start PT target, presputter 2 minutes and then rotate substrate to coincide with the PT target. Sputter for 1 minute. Film should be $\approx$ 500 Å thick.
i. Start Au target, presputter 2 minutes and then rotate substrate to coincide with the Au target. Sputter for 4 1-minute cycles. Film should be $\approx$ 2000 Å thick.

j. Turn off RF generator. Turn off gas. Press start-stop. When chamber vents, open and remove wafer and place in clean covered petri dish.
k. Close chamber and press start pump.

7. Quality Assurance

A thickness gauge partially masked with a portion of glass cover slip will be placed beside the wafer during the metallization runs. The monitor may be a glass cover slip or a piece of scrap polished GaAs. Selective etching or SEM analysis will be used to determine the thicknesses.

a. Cleave sample and mount on an SEM stub, with cleaved edge up.
b. Etch in 60 °C techni-strip Au for 10 seconds. Then rinse in di water for 30 seconds. This delineates Au film. 2000 $\pm$ 500 Å
c. Etch in 10% HF for 10 seconds then rinse in di water for 30 seconds. Blow dry using $N_2$ gas. This delineates Ti film. 1000 $\pm$ 200 A
d. Platinum film remains unaffected. 500 $\pm$ 100 Å
e. SEM photomicrographs will serve as file data.

OR: If a GaAs Thickness Gauge is used.

a. Mount the piece in blackwax onto a glass slide.
b. Mask off all but a 1 mm strip of metallized area orthogonal to the pre-metallization mask.
c. Etch in 60°C Technistrip to remove the gold metallization. Then rinse in Di water. This creates the gold platinum step.
d. Etch in 10% HF for 1 minute. This etches the titanium under the platinum, creating a platinum titanium step. Then rinse in DI water and $N_2$ blow dry.
e. Remove wax using Trichloroethylene.
f. Step profile the resultant etch steps on the Alpha Step Profiler.
g. Attach the profile data to the run sheet.

SCOPE

To determine the I vs. V characteristic of the diodes and while still in wafer form, determine the diode uniformity across the wafer.

APPLICABLE DOCUMENTS

Contract Number S8-738203-LV3
Hughes Drawing 3414270 Rev ( C )

REQUIREMENTS

1. Equipment - set up in air conditioned, RF shielded room.

   a. Curve tracer, Tektronix model 576
   b. Digital voltmeter, Keithley model 191
   c. 22V Battery Supply
   d. Probe station with 1 mil pointed whisker, lab built
   e. Lab built constant current source
   f. Microscope, boom mounted, Bausch and Lomb 7-30x

2. Procedure - Connect equipment 1a, b, c, and d as shown in Figure 1, constant current source.

   a. Turn Diode switch to curve tracer.
   b. Set max peak volts units to 20 V max
   c. Polarity, NPN
   d. Series resistance, 5 K
   e. Horizontal to .1 V/cm
   f. Vertical to .01 mA/cm
   g. Adjust intensity and focus for clear display
   h. Adjust graticule illumination

3. Place wafer on probe station platform. Perform the measurements on three evenly spaced areas of the wafer, in accordance with the wafer map shown in Figure 2.

   a. Adjust curve tracer sweep to .8 V (8 cm)
   b. Lower whisker probe, adjusting X, Y, Z knobs as needed until whisker contacts one diode, indicated by a vertical jump in the trace.
   c. Further adjust sweep volts until a full scale display is observed.
   d. Switch curve tracer vertical to 1 mA/cm and increase sweep volts to indicate 5 mA of vertical display.

e. Carefully increase or decrease contact pressure while observing curve tracer display. Adjust for steepest slope. CAUTION! Too much downward movement may dislodge the whisker or grossly affect the knee portion of the trace. The knee should remain as sharp as when first contacted in step 3c. Turn sweep volts to zero.

4. Measure and record reverse breakdown.

a. Switch polarity to PNP
b. Move sweep start to right side center of screen
c. Set horizontal to 2 V/cm
d. Set vertical to .01 mA/cm
e. Turn up sweep volts to display diode breakdown volts when indicating 0.001 mA current.
f. Position polaroid camera to photograph display, or record voltage displayed on I-V data sheet.
g. Turn down sweep and turn diode switch to current source.

5. Record forward I-V data

a. Set current switch to lowest setting ccw, 0.01 microamperes.
b. Read and record voltage on Keithly model 191 DVM.
c. Turn current switch to next current, 0.10 microamperes - Repeat step b. for each current setting.
d. Return current switch to lowest setting and turn diode switch back to curve tracer.
e. Record the I-V data indicating the map area on 7-cycle semilog graph paper, or enter data into a preprogrammed calculator with printer such as the HP 41C and HP 82143A.
f. Determine diode quality factor $\eta$, and series resistance $R_s$ from the following equations.

$$\eta = (\Delta V \text{ 100 } \mu A/.0583) \times (296/T)$$

T = room temperature °K

$$R_s = (\Delta V_{1.0\ mA} - \Delta V_{100\ \mu A}) \times 1000$$

If the test results are acceptable, the wafer is now ready for scribing PI-11.

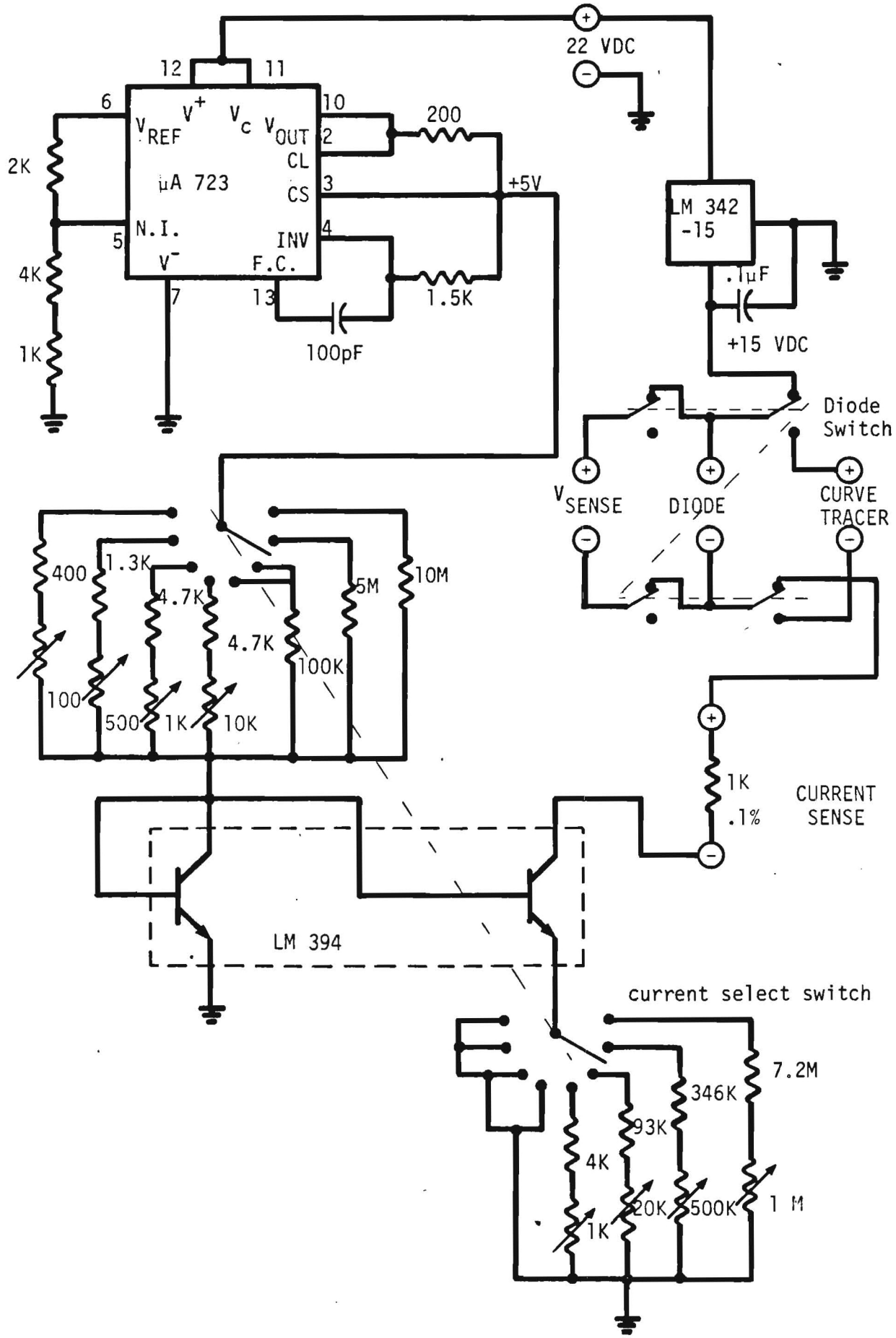
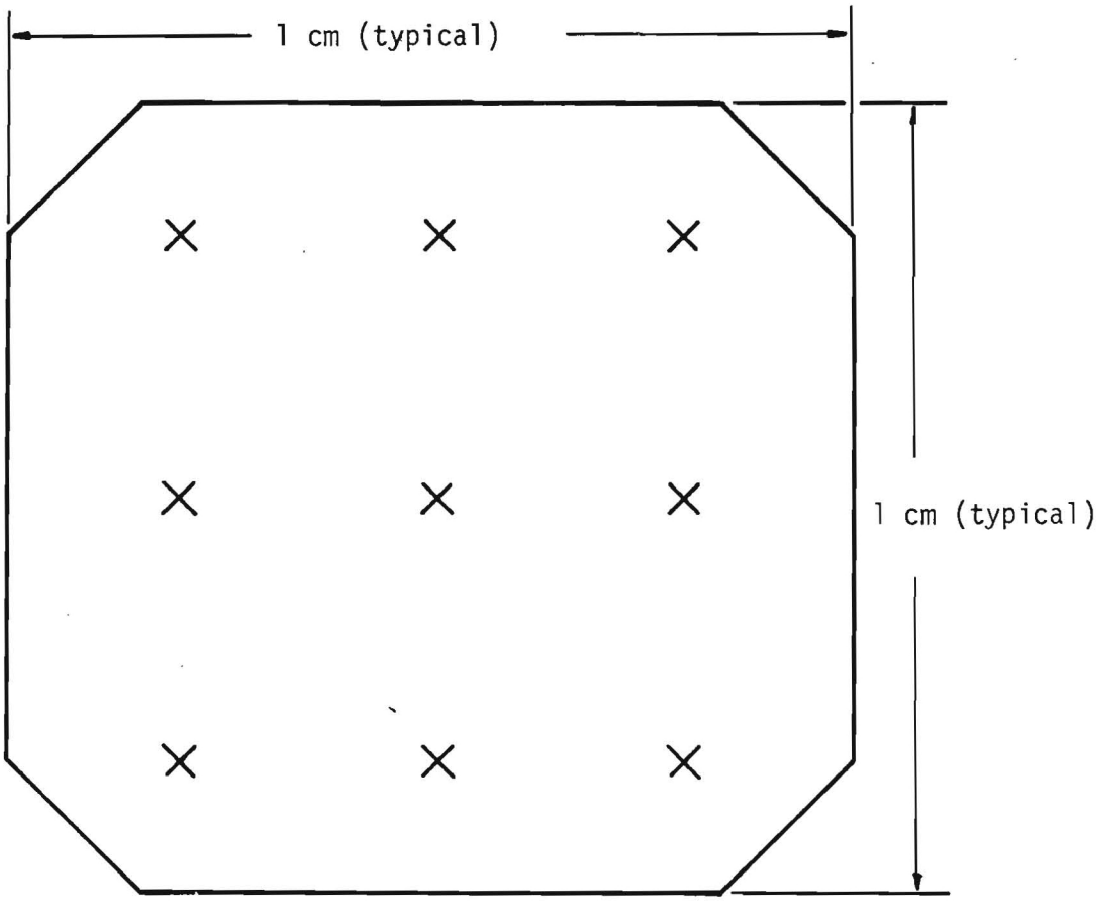



Figure 1. Schematic Diagram - Constant Current Source.




PI-10

Figure 2. Wafer Map

| I | V | ΔV |
|---|---|---|
| 0.1 μA | | |
| 1.0 | | |
| 10.0 | | |
| 100.0 | | |
| 1.0 mA | | |
| 3.16 mA | | |
| 10.0 mA | | |
| | | |

Date: _____

Wafer No.: _____

Diode No.: _____

Temperature: _____

$R_S$ = _____

$n$ = _____

$V_B$ = _____(at 1.0)

$$R_S = (\Delta V_{1.0mA} - \Delta V_{100\mu A}) \times 1000$$

$$n = (\Delta V_{100\mu A}/.0583) \times (2.96/T)$$

T = Ambient temperature, °K

[$V_B$ need not be supplied for all diodes; just for a representative sample]

PI-10

Table 1. Typical I-V Test Data, Hughes 3414271 Rev. (C).

SCOPE

Describes the procedure for dicing the wafer into individual chips

APPLICABLE DOCUMENTS

Contract Number S8-738203-LV3
Hughes Drawing 3144270 Rev (C)

REQUIREMENTS

1. Equipment set up in an air conditioned, limited access facility.

   a. Tempress Automatic wafer scriber model 1713-10C
   b. Hot plate, HPA1915B
   c. Fume hood
   d. Sundry supplies. Parafin wax, glass cover slips, beakers, filter paper, tweezer, plastic storage containers, labels, stainless steel screen, fine mesh.
   e. Microscope, General purpose, 7-30x Baush & Lomb

2. Chemicals and gases electronic grade or equivalent high purity.

   a. Trichloroethylene
   b. Nitrogen gas 99.994%

3. Procedure - Mount wafer to a heated glass cover slip.

   a. Apply parafin wax to cover slip
   b. Place wafer face up in wax
   c. Remove excess wax using trichloroethylene
   d. Remelt wax to form a bead around wafer edge

4. Place mounted wafer on scriber chuck.

   a. Turn on machine power
   b. Turn on vacuum
   c. Set mode to index, and spacing to .015
   d. Align scribe streets with cross hair in eyepiece
   e. Translate the wafer well to the left of the scribe point
   f. Adjust the point height to just touch the cover slip. Manually cycle once to determine planarity. If not in plane, adjust accordingly.
   g. Increase the scribed point height 1 to 1.5 mils
   h. Reposition wafer to align its scribe street with point

i. Begin scribe stroke. Single stroke operation is recommended to avert catastrophe. When one axis is completed, rotate stage 90° and repeat the operation. Blow clean occasionally using $N_2$ gas.

5. Remove wafer from machine.

   a. Blow dust off surface using $N_2$ gas
   b. Carefully dissolve wax from wafer by soaking in trichloroethylene. Pour off several times after the wafer comes free of the cover slip.

6. Break into chips.

   NOTE: This procedure is temporary

   a. Place wafer scribed side up between halves of a folded sheet of lens tissue.
   b. Grip tissue, keeping it taut and trapping the wafer
   c. Pass the underside of the tissue over a sharp, smooth edge of an aluminum block. Use just enough pressure to break the wafer. Remember to keep tissue taut. Then rotate the tissue 90° and repeat.
   d. Rinse the chips in methanol over a fine stainless steel screen to remove particulate matter.
   e. Oven dry 85 °C for 10 minutes

7. Quality Assurance

   a. Pour chips into a clean covered box
   b. Inspect chips for poor edges, cracks, flaking of back metallization or other obvious flaws.
   c. Label container